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OF

AMERICA

VOL. 13

JOSEPH STANLEY-BROWN, *Editor*

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PUBLICATIONS OF THE GEOLOGICAL SOCIETY OF AMERICA

Regular Publications

The Society issues a single serial octavo publication entitled Bulletin of the Geological Society of America. This serial is made up of *proceedings* and *memoirs*, the former embracing the records of meetings, with abstracts and short papers, list of Fellows, etcetera, and the latter embracing larger papers accepted for publication. The matter is issued as rapidly as practicable, in covered brochures, which are at once distributed to Fellows and to such exchanges and subscribers as desire the brochure form of distribution. The brochures are arranged for binding in annual volumes, which are elaborately indexed. To this date thirteen volumes have been published and an index to the first ten volumes.

The Bulletin is sold to Fellows of the Society and to the public either in separate brochures or in complete (unbound) volumes. The *prices* are as follows: To libraries and to persons residing outside of North America, five dollars ($5.00) per volume; to persons in North America, not Fellows of the Society, ten dollars ($10.00) per volume (the same amount as the annual dues of the Fellows); to Fellows of the Society, a variable amount, depending on the cost of publication. These prices cover cost of transmission to all parts of the globe. No reduction is made to dealers. Subscribers should specify whether they desire the brochures or the completed volume. Orders should be addressed to the Secretary, and drafts and money orders made payable to the *Secretary of the Geological Society of America*, Rochester, New York.

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Volumes.	Pages.	Plates.	Figures.	Price to Fellows.
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Brochures of Volume 13

Brochures.	Pages.	Plates.	Figures.	Price to Fellows.	Price to the Public.
Proceedings of the Thirteenth Summer Meeting, held at Denver, Colorado, August 27, 1901. H. L. Fairchild, *Secretary*	1- 16	....	....	$0.20	$0.40
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Geology of the northeast coast of Brazil. J. C. BRANNER	41–98	4–15	1–19	1.25	2.50
Outlook of the geologist in America. C. D. WALCOTT	99–118	....	....	.15	.30
Geological horizon of the Kanawha black flint. I. C. WHITE	119–126	....	....	.10	.20
Origin and distribution of the loess in northern China and central Asia. G. F. WRIGHT	127–138	16–21	1	.35	.70
Former extent of the Newark system. W. H. HOBBS	139–148	....	1–5	.10	.20
Hamilton group of Thedford, Ontario. H. W. SHIMER and A. W. GRABAU	149–186	....	1–5	.45	.90
Geology of the Potomac group in the Middle Atlantic slope. W. B. CLARK and A. BIBBINS	187–214	22–28	1	.60	1.20
Correlation of the Coal Measures of Maryland. W. B. CLARK and G. C. MARTIN	215–232	29–39	....	.70	1.40
Geological section of the Rocky mountains in northern Alaska. F. C. SCHRADER	233–252	40–43	....	.40	.80
Geological reconnaissances in southeastern Alaska. A. H. BROOKS	253–266	....	1	.20	.40
Devonian interval in Missouri. C. R. KEYES	267–292	44	....	.25	.50
Rock basins of Helen mine, Michipicoten, Canada. A. P. COLEMAN	293–304	45	1–2	.15	.30
Stratigraphy and structure, Lewis and Livingston ranges, Montana. BAILEY WILLIS	305–352	46–53	1–6	1.00	2.00
Copper-bearing rocks of Virgilina copper district, Virginia and North Carolina. T. L. WATSON	353–376	54–56	1	.40	.80
Catalog of photographs belonging to Geological Society of America. N. H. DARTON	377–474	....	....	1.10	2.20
Proceedings of the Fourteenth Annual Meeting, held at Rochester, New York, December 31, 1901, and January 1 and 2, 1902, including proceedings of Third Annual Meeting of the Cordilleran Section, held at San Francisco, December, 30 and 31, 1901. H. L. FAIRCHILD, *Secretary*	475–583	57–58	....	1.50	3.00

IRREGULAR PUBLICATIONS

In the interest of exact bibliography, the Society takes cognizance of all publications issued wholly or in part under its auspices. Each author of a Memoir receives 30 copies without cost, and is authorized to order any additional number at a slight advance on cost of paper and presswoork; and these separate brochures are identical with those of the editions issued and distributed by the Society.

Contributors to the proceedings are also authorized to order any number of separate copies of their papers at a slight advance on cost of paper and presswork; but such separates are bibliographically distinct from the brochures issued by the Society.

The following separates of parts of volume 13 have been issued:

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Pages	17– 26, plates 1– 2:	230 copies.	December	28, 1901.
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CORRECTIONS AND INSERTIONS

All contributors to volume 13 have been invited to send corrections and insertions to be made in their papers, and the volume has been scanned with some care by the Editor. The following are such corrections and insertions as are deemed worthy of attention:

Page 1, line 8 from top; *insert* after "Wisconsin" [abstract]
" 46, " 12 " " ; *for* "Permbuyo" *read* Pernambuco
" 56, " 26 " " ; *for* "Parahiba" *read* Parahyba
" 59, " 20 " " ; *for* "6 centimeters" *read* 6 millimeters
" 72, top of hills in figure 11 should be horizontal
" 74, line 3 from bottom; *for* "Dombre do Interior" *read* Dombre ao Interior
" 144, " 8 " top; *for* "ashed" *read* dashed
" 164, " 8 " " ; *after* "*Centronella impressa* Hall" *insert* characteristic, but not restricted.

Page 176, line 4 from top; *for* "var. nov." *read* sp. nov.
" 184, " 4 " " ; *for* "157. *T. incrassata*" *read* *F. incrassata*
" 202, plate 27; *for* "White Rooks" *read* White Rocks
" 223, " 35: *for* "crinoidal limestone" *read* crinoidal coal
" 237, line 17 from top; *before* "range" *insert* a
" 246, " 5 " bottom; *after* "(Cretaceous)" *insert* ?
" 251, " 7 " " ; *for* "between" *read* beyond
" 323, plate 49; *for* "northwest" *read* northeast
" 330, " 50, figure 2; *for* "Knitla" *read* Kintla
" 330, " 51, " 1; *for* "south by east" *read* south by west
" 338, line 5 from bottom; *for* "Cretaceons" *read* Cretaceous
" 537, line 18 " " ; *for* "O. Saint John" *read* H. O. St John
" 537, lines 5 and 13 from bottom; *for* "state quarry" *read* State Quarry

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 13, PP. 1-16 DECEMBER 27, 1901

PROCEEDINGS OF THE THIRTEENTH SUMMER MEETING, HELD AT DENVER, COLORADO, AUGUST 27, 1901

HERMAN LE ROY FAIRCHILD, *Secretary*

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SESSION OF TUESDAY, AUGUST 27.

The Society was called to order at 9.15 o'clock a m, in room 2, Denver High School building. In the absence of the President, the first Vice-President, Professor N. H. Winchell, presided throughout the meeting.

ELECTION OF FELLOWS

The Secretary announced that the candidates for fellowship had received a nearly unanimous vote of the ballots sent, and that they were elected, as follows:

Fellows Elected

CHARLES PETER BERKEY, Ph. D., Minneapolis, Minn. Instructor in Mineralogy, University of Minnesota.

EDGAR ROSCOE CUMINGS, A. B., Bloomington, Ind. Instructor in Geology, Indiana University.

HERBERT ERNEST GREGORY, Ph. D., New Haven, Conn. Assistant Professor of Physiography, Yale University.

FREDERICK BURRITT PECK, Ph. D., Easton, Pa. Professor of Geology and Mineralogy, Lafayette College.

FRANK CHARLES SCHRADER, M. S., A. M., Washington, D. C. Assistant Geologist, United States Geological Survey.

Edward Martin Shepard, A. M., Springfield, Mo. Professor of Geology, Drury College.

William John Sutton, B. S., E. M., Victoria, B. C. Geologist to E. and N. Railway Company.

Alexander Newton Winchell, M. S., Butte, Mont. Professor of Geology and Mineralogy, Montana State School of Mines.

The reading of papers was declared in order. The first paper presented was

HYDROGRAPHIC HISTORY OF SOUTH DAKOTA

BY J. E. TODD

The paper was discussed by S. F. Emmons, H. T. Fuller, A. C. Lawson, and the author. It will be printed in this volume.

At the close of the discussion of Professor Todd's paper a recess was voted in order to allow attendance at the opening general session of the American Association for the Advancement of Science. The Society reconvened at 10.25 o'clock.

It was announced by the Secretary that the American Association for the Advancement of Science had adopted an amendment to its constitution under which societies affiliated with the Association were to be represented by delegates on the Council of the Association, and that the Geological Society was entitled to two such delegates.

Vice-President S. F. Emmons moved that the President and Secretary of the Society be *ex officio* the delegates, and it was so voted.

The reading of papers was resumed, and the first paper was an informal presentation of the following account of the

GEOLOGICAL EXCURSION IN COLORADO

BY C. R. VAN HISE

It has long appeared to me that the most important services to geology which a summer meeting of geologists can accomplish are a common study of the phenomena of geology in the field and a mutual exchange of views. For a comparison of views no other place is so well adapted as the field. Having held these opinions for a number of years, I planned an excursion in the Lake Superior region at the time of the meeting of the American Association for the Advancement of Science, at Madison, Wisconsin, in 1893. This excursion was attended by about thirty geologists. It continued for a week, and during that time two of the more important iron-bearing districts and the copper-bearing district of Keweenaw point were visited. The evident pleasure and profit of those taking part in the Lake Superior excursion encouraged me to suggest a Colorado excursion preceding the meeting of the American Association for the Advancement of Science and the Geological Society of America at Denver. I presented the subject to Messrs S. F. Emmons and Whitman Cross, and they, being more familiar with Colorado geology than I, kindly prepared an itinerary for the proposed excursion. This itinerary was sent to the geologists of the country, and a sufficient number of responses followed to warrant carrying out the plan. Mr Emmons also spent much time in correspondence with Colorado mining men and in perfecting arrangements with the railroads.

The rendezvous for the excursion was at Denver, August 15. The party consisted of R. M. Bagg, Jr., Colorado Springs, Colorado; H. F. Bain, Idaho Springs, Colorado; E. H. Barbour, Lincoln, Nebraska; J. C. Branner, Stanford University, California; Samuel Calvin, Iowa City, Iowa; G. L. Cannon, Denver, Colorado; R. T. Chamberlin, Chicago, Illinois; T. C. Chamberlin, Chicago, Illinois; C. R. Eastman, Cambridge, Massachusetts; S. F. Emmons, Washington, District of Columbia; H. L. Fairchild, Rochester, New York; J. W. Finch, Victor, Colorado; U. S. Grant, Evanston, Illinois; J. C. Hersey, Leadville, Colorado; V. G. Hills, Cripple Creek, Colorado; J. D. Irving, Washington, District of Columbia; W. S. Kelley, Leadville, Colorado; Arthur Lakes, Denver, Colorado; H. C. Lay, Telluride, Colorado; J. R. Macfarlane, Pittsburg, Pennsylvania; J. D. Newsom, Stanford University, California; H. B. Patton, Golden, Colorado; A. H. Purdue, Fayetteville, Arkansas; C. W. Purington, Chester, Massachusetts; W. N. Smith, Madison, Wisconsin; C. R. Van Hise, Madison, Wisconsin; A. N. Winchell, Butte, Montana. Some of these men, however, were not with the excursion throughout the entire trip.

Professor T. C. Chamberlin acted as leader for physiography and the Pleistocene, and Mr Emmons acted as leader for economic geology as far as Ouray.

The itinerary of the excursion and the lines of study at the various points are briefly as follows:

First day (August 16). The party left Denver in the morning, following the plains along the base of the mountains to Canyon City, at the mouth of the Royal Gorge of the Arkansas.

Here Mr J. B. Hatcher met the party, and personally conducted it to the Dinosaur quarries about 9 miles north of Canyon City, up Four-mile creek. Mr Hatcher had a party at work quarrying the bone-bearing beds of the Jurassic, and for the first time a number of the party saw Dinosaur bones in place. During the drive an excellent section of the Colorado formations from the Silurian to the Jurassic was seen along the front of the mountains.

Second day (August 17). The party divided. The larger number of the party went on foot from Canyon City through the Royal Gorge of the Arkansas to Parkdale, a distance of 11 miles. The major part of this distance furnished a magnificent section of the Archean complex in typical development. At Parkdale a very interesting basin of Mesozoic rocks resting upon the pre-Cambrian was seen. That portion of the party remaining at Canyon City occupied the morning in studying the locality containing Silurian fish, studied and described by Walcott. The train carrying the united party left Canyon City at 1.15 p m, following the Arkansas valley to near Leadville, over the Tennessee pass, and thence down the valleys of the Eagle and Grand rivers to Glenwood Springs; thence to Aspen.

Third day (August 18). The entire day was spent at Aspen, studying the mines, the complex faulting of the Paleozoic strata, and the glacial phenomena. The party left Aspen in the evening for Grand Junction, Fourth day (August 19). The party went from Grand Junction to Ouray. The route is along the great mesa plains of the Colorado basin. The horizontal Mesozoic and Tertiary beds extended all the way from Grand Junction to the San Juan mountains at Ouray. Arriving at Ouray at 3.30 p m, a drive was taken up the beautiful Red Mountain stage road, affording fine views of the precipitous Red Mountain canyon. Along the road is exposed a good section of Algonkian quartzites and slates.

Fifth day (August 20). The entire day was spent in visiting the Camp Bird mine and mill, several miles south of Ouray. The Camp Bird mine is a great fissure vein in Tertiary andesitic breccias, and it afforded the first good opportunity for the party to study the ore deposits of the San Juan district.

Sixth day (August 21). The party divided, a part going by train from Ouray to Telluride, and a part over the beautiful Virginius pass, 13,000 feet high. This ride furnished a fine opportunity for studying the glacial cirques of the San Juan district, and also allowed those interested in ore deposits to visit the Virginius and Liberty Bell mines.

Seventh day (August 22). The day was spent at Telluride and vicinity. About half of the party studied the glacial and physiographic features of the vicinity, taking a carriage ride to the Alta mine, 10 miles southwest of Telluride, and the other half examined the Smuggler Union and Tomboy mines. The district was of interest to all from a structural point of view. The Triassic beds are finely exposed, and the unconformity at the base of the San Miguel conglomerate, which underlies the volcanics, is clearly marked.

Eighth day (August 23). From Telluride to Silverton. The party again divided, some going by train via Rico and Durango, while a number rode from Telluride to Red Mountain, over the Ingram pass, 12,700 feet, and thence by train to Silverton. Those on horseback had an opportunity to observe the red mountains of the district, called "blow outs" by the miners.

Ninth day (August 24). The division of the party interested in ore deposits studied the Silver Lake and Royal Tiger mines. Another division of the party walked down the Las Animas canyon from Silverton to Needleton, 15 miles, in order to study the Algonkian and Archean rocks and their relations. Both of these series are magnificently exposed in this canyon.

Tenth day (August 25). En route from Silverton to Denver via Durango, Antonito, Alamosa, and Pueblo. The entire Mesozoic-Paleozoic-pre-Cambrian succession of southwestern Colorado is exposed along the railroad from Silverton to Durango. From Durango for a considerable distance the train passed over gently dipping Cretaceous rocks. At Toltec gorge the Archean was seen for the last time, and from Toltec gorge to the San Luis valley a recent volcanic plateau was traversed.

The party arrived at Denver the morning of the eleventh day, August 26, having traveled almost 1,400 miles.

As far as Grand Junction the railroad is standard gauge, and for this distance the party had a special Pullman sleeper. From Grand Junction to Alamosa the road is narrow gauge, and during this part of the excursion there was no night traveling. Over this part the Denver and Rio Grande railway placed at our disposal a special day coach. From Alamosa to Denver a special sleeper was again available.

Everywhere the party was treated by the citizens of Colorado as distinguished guests, and the best that the various places afforded was at their disposal. The mine owners, superintendents, and engineers at each mine visited gave their time to assist those interested in mines in their studies. We are especially indebted to Mr H. C. Lay, of Telluride, who was interested in the excursion from the first. At Aspen we were the guests of Mr F. T. Freeland, Mr J. B. Gwinn, Mr. Woodward, and the other mining men of the city. At Ouray we were the guests of Mr T. F. Walsh, and were magnificently entertained both at Ouray and at the Camp Bird mine. At Telluride the citizens showed us many courtesies and attentions. Mr Arthur Collins, who is in charge of the Smuggler Union property at Telluride, entertained the party at his mines, and furnished us every opportunity for studying the ore deposits. Among others to whom the party is indebted for many courtesies may be mentioned Messrs J. W. Benson, D. R. Reed, A. Richardson, H. W. Reed, and E. A. Krisher, of Ouray; Messrs E. I. Fields, C. R. Van Law, John Herron, A. Koch, J. K. McCoy, and Charles A. Chase, of Telluride; Messrs S. J. Hallett, G. H. Stoiber, and R. W. Watson, of Silverton, and Mr J. O. Campbell, of Durango.

The various members of the party expressed themselves as being highly pleased with the excursion. And if it is advantageous to rapidly go over a considerable part of a great region in order to obtain a large view; if it is advantageous for geologists to see the same phenomena together, or, in other words, to be able to see with one another's eyes; if it is advantageous for geologists to interpret phenomena together, or to interpret with one another's brains; if it is advantageous for geologists interested in similar problems to confer with one another as to geological phenomena and their meaning, then the excursion was well justified. In many cases the field experience of a man has been somewhat narrow; his capacity to correctly observe and discriminate the important phenomena in an area, to understand their relations, to understand their meaning in the terms of the principles of physics and chemistry and biology, is somewhat limited. In many instances, in consequence of isolation, peculiar or partial views have been developed. All of these defects may be partially removed or corrected by mutual study of the same field.

By a rapid review of a great region the large and salient points are discriminated from the minor, and in some cases less important ones. One whose power of observation is imperfect finds that other men perceive many things that his eyes do not see, and his vision is thereby improved. One who is defective in his method of observation or reasoning is sure to realize these defects when he compares himself with others more fortunate in the capacity to perceive facts and to apprehend their meaning.

In consequence of the Colorado excursion we who participated in it hope we are somewhat more accurate observers, somewhat better interpreters of phenomena, and somewhat more capable of carrying on our investigative or instructional work than before the excursion. If this be so, it would seem that the dominating feature of the summer meetings of geologists should hereafter be extended excursions, although this by no means prevents the advantages which result from the presentation of papers and the discussion of them at the regular meeting.

The following paper was then read by the author:

JUNCTION OF LAKE SUPERIOR SANDSTONE AND KEWEENAWAN TRAPS IN WISCONSIN *

BY U. S. GRANT

[*Abstract*]

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Early Investigations

In the early days of geological investigation in the Lake Superior region two sandstone series were recognized on the south shore of the lake—one a tilted series, which conformably overlies the Keweenawan or copper-bearing igneous rocks, and the other a flat-lying series, found only at low altitudes on or adjacent to the lake shore. The name Lake Superior sandstone was applied to the flat-lying sandstones, and these were separated into two divisions, designated as the Eastern and Western sandstones. These divisions were based largely on geographical position, the former lying on and to the east of Keweenaw point and being confined to the state of Michigan, and the latter lying to the west of this point in Wisconsin and Minnesota.

Results of later Study

Differences of opinion arose in regard to the relations and relative ages of the Eastern sandstone and the Keweenawan traps, some holding that one and some that the other was the older. This was a significant question, for on its solution depended not only the age of the great copper-bearing series, but also important facts in the history of a region which was destined to become, both from its economic and also from its geologic features, the classic and typical pre-Cambrian district for America, if not for the world. It was not until the detailed observations of Professors Irving and Chamberlin, made along the junction of the two formations, were published in 1885 that a satisfactory solution of the problem was proposed.† Their conclusions are today generally accepted by students of Lake

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* Published with the permission of Professor E. A. Birge, director of the Wisconsin Geological and Natural History Survey. Local details of this junction may be found in Bulletin VI of the Wisconsin Geol. and Nat. Hist. Survey, pp. 17–20, 1900.

† Observations on the junction between the Eastern sandstone and the Keweenawan series on Keweenaw point, lake Superior, U. S. Geol. Survey, Bulletin 23, 1885. Here complete references to the literature of the subject may be found.

Superior geology. In brief these conclusions are as follows: The junction between the Eastern sandstone and the Keweenawan traps is along a fault. The displacement in the traps began before the deposition of the sandstone. The sandstone was deposited along a shore cliff formed by the fault scarp. Since the deposition of the sandstone further displacement has occurred along this earlier line of faulting. Thus the apparently inferior position of the sandstone is due, not to the fact that the sandstone is older than and underlies the traps, but to faulting in part subsequent to its deposition; the Keweenawan traps belong to the upper division (Algonkian) of the pre-Cambrain, while the sandstone belongs to the upper half of the Cambrian. The two formations are thus separated by an unconformity.

Comparison of South and North Side of Lake Superior Syncline

All this is on the south edge of the Lake Superior syncline. When the junction of the Lake Superior sandstone and the Keweenawan traps along the north side of this syncline is considered, it is found to be a marked coincidence that the relations of the two formations, at least as far as faulting is concerned, are very similar to those already described. Mr E. T. Sweet,* on the former Geological Survey of Wisconsin, collected data along this line of junction, and from this data Professors Chamberlin † and Irving ‡ inferred that a fault existed here. While employed by the present Geological and Natural History Survey of Wisconsin, the writer had occasion to study this junction of the sandstone and traps, and to obtain information which demonstrates conclusively, even more conclusively than on Keweenaw point, the faulting and the later age of the sandstone.§

Features of Contact

CONTACT LINE

This contact line of the two series has an east and west direction in Douglas county, Wisconsin, being in general parallel to the lake shore and lying only a few miles from it. The most important phenomena presented may be classed under three heads: topography, effect on the traps, effect on the sandstone.

TOPOGRAPHY

In passing southward from the west end of the lake one crosses a monotonous plain which abuts against an east and west ridge known as the Douglas copper range. The north slope of this ridge is abrupt, and its summit is 100 to 300 feet above the plain. The plain is underlain by the Lake Superior sandstone in horizontal beds, and the ridge consists of lava flows dipping steeply toward the south. The sandstone in general is not firmly cemented and is easily eroded, while the traps or lava flows are much more resistant to erosion. The abrupt northward slope of the trap ridge functions as a fault scarp, although by this statement it is not intended to convey the idea that the faulting has been recent, nor that erosion has not kept pace with it; on the other hand, the present scarp is regarded as a result of differential erosion.

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* Geol. of Wisconsin, vol. iii, pp. 340-350, 1880.

† Geol. of Wisconsin, vol. i, p. 105, 1883.

‡ U. S. Geol. Survey, Monograph v, p. 258, 1883.

§ Wisconsin Geol. and Nat. Hist. Survey, Bulletin vi, 1900.

EFFECT ON THE TRAPS

One of the most conspicuous features of the faulting is the extremely intense brecciation of the igneous rocks near the contact. This has been so thorough that frequently these rocks are so shattered that a fragment an inch in diameter can not be found which is not crossed by one or more fractures; and this fractured zone extends in some cases more than 400 feet from the junction of the two formations. Generally there has been no appreciable motion of these fragments on one another, but in places the fragments are slickensided, and but rarely has the motion been sufficient to round them.

EFFECT ON THE SANDSTONE

The sandstone, except at one locality to be mentioned later, does not exhibit the brecciation common to the traps. The usual altitude of the sandstone near the junction is a bending upward of the layers so that they have a marked northerly dip, but the amount of the dip rapidly diminishes on leaving the contact, and the layers soon assume their normal position of practical horizontality.[*] Sometimes this simple relation is complicated by minor faulting or folding in the sandstone, the details of which have not been yet worked out. At one locality, however, the sandstone has been more profoundly affected and has been thrown into an anticlinal fold of considerable dimensions.[†] The southern limb of this fold, which limb is nearly half a mile across, dips steeply toward the south under the traps. Immediately at the contact there is evidence, as pointed out by Professor C. R. Van Hise, of a small sharp syncline. Here the upper part of the sandstone is as intensely brecciated as are the traps.

CONTACT PLANE

In two localities the actual contact plane of the two formations is nearly or quite exposed, and here this plane has a noticeable hade toward the south—that is, toward the upthrow side. This, together with the structures in the sandstone already mentioned, marks the displacement as a reversed or thrust fault, the traps, which are older rocks, being on the south or upthrow side and the sandstone being on the north or downthrow side.

CONGLOMERATIC BEDS

By the faulting some conglomeratic beds of the sandstone are brought to view. The pebbles are all well rounded, and are composed mainly of rocks which can be referred to the more firm and silicious parts of the adjacent, but not necessarily immediately adjacent, traps. With these trap pebbles are some of vein quartz, and at one locality pebbles of quartzite, which as far as known cannot be duplicated in this vicinity, are common. Thus the evidence that there was displacement here before the deposition of the sandstone, and that the sandstone was deposited against a fault scarp shore cliff, and that there has been little displacement since, is not clear. The relations here are thus different from those at the junction of the two formations on Keweenaw point. It is only just to state, however, that in Wisconsin all the information to be had from a detailed study of this contact and these pebbles is not at hand.

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[*] Ibid., p. 19 and pl. 8, section AB.

[‡] Ibid., p. 20 and pl. 9, section CD.

Thickness of Sandstone Series

Where the sandstone has been thrown into an anticline of considerable dimensions, as already mentioned, an opportunity is had to measure the thickness of this series. (In passing, it may be of interest to note that in geological work done some years ago there was at times a tendency to mistake secondary cleavage for bedding, and thus to make possible enormously large estimates of the thickness of certain formations. At this locality, however, the opposite and very uncommon mistake was made, and bedding and accompanying cleavage were regarded as purely secondary, while a series of horizontal joints were clearly thought to be bedding planes.*) On the southern limb of this anticline, which is about 3,000 feet across and along which exposures are pretty continuous, the dip averages approximately 70 degrees toward the south. This gives a thickness, as exposed, of about 2,160 feet. It is not unreasonable to suggest that the total thickness of the sandstone at this locality does not greatly exceed this figure, for the upper beds are marked shales, which in places are highly charged with lime, thus possibly representing the beginning of the physical changes which brought on the epoch of the Lower Magnesian limestone, a formation which overlies the Lake Superior sandstone in the northern peninsula of Michigan, but which is not known in the western part of the Lake Superior basin; and the lowest beds exposed along the axis of the syncline are quite coarse, and even conglomeratic, thus indicating a possible approach to the base of the series. This estimate of the thickness of the Lake Superior sandstone is regarded as conservative; still it shows that the formation is of considerably greater vertical dimensions than has been commonly supposed.†

Amount of Displacement

In regard to the amount of this displacement data are not complete; but it is very probable that the throw increases from west to east, and the amount of displacement on the east, where the sandstone has been thrown into the anticline just noted, equals at least the thickness of the exposed strata, or over 2,100 feet. How much more it is impossible to state, although to this figure we can add something for the lower unexposed strata of the sandstone, and to this at least the present vertical distance to which the traps near the junction rise above the sandstone. A total vertical displacement of some 2,500 feet is thus quite clear, and not improbably the distance is greater than this.‡

Professor Grant's paper was discussed by C. R. Van Hise and A. C. Lawson.

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* Geol. of Wis., vol. iii, p. 347, 1880.

† From a well-boring at Ashland, Wisconsin, the thickness of the Lake Superior sandstone has been stated to be over 2,500 feet (G. L. Collie, this Bulletin, vol. 12, p. 200, 1901). The writer is not aware that any detailed study of the borings from this well has been made. Such a study might show that some of the sandstone penetrated had the lithological characters of the Upper Keweenawan sandstone, which is here thought to underlie the Lake Superior sandstone at an undetermined depth.

‡ Since this paper was written and presented another paper has appeared (C. W. Hall, this Bulletin, vol. 12, pp. 313-342, 1901), in which is presented evidence for the extension of this fault plane for a considerable distance to the southwest in Minnesota.

The following four papers were read by title:

STILL RIVERS OF WESTERN CONNECTICUT

BY W. H. HOBBS

This paper is printed in full in this volume.

GEOLOGY OF THE NORTHEAST COAST OF BRAZIL

BY JOHN C. BRANNER

The paper is printed in this volume.

CLASSIFICATION OF THE GEOLOGICAL FORMATIONS OF TENNESSEE

BY JAMES M. SAFFORD

In the spring of 1900 I had occasion to construct a table of formations for a small text-book on the geology of Tennessee.*

The table includes the more recently recognized formations, introduces some changes, and notices certain errors that have been made. It was constructed, as will be seen, for Tennessee. Local names are used in many cases and for two reasons: first, to bring the subject more nearly home to the student, and, second, because many of the formations have a more or less local development.

For brief descriptions of the formations, other than those contained in the table and notes, the reader is referred to the text-book cited in the foot-note.

Table of the geological Formations of Tennessee

Eras.	Periods.	Epochs.
V. Cenozoic.	Recent. *Quaternary.*	36. Alluvium.
	Pleistocene. *Quaternary.*	35. Milan loam. (Yellow loam.) 34. Memphis loess. (Bluff loam.)
	Neocene. *Tertiary.*	33. Lafayette. (Orange sand; Bluff gravel.)
	Eocene *Tertiary.*	32. La Grange. (Lignitic; Flatwoods; Bluff lignite.) 31. Middleton. (Clayton; Porters creek.)
IV. Mesozoic.	Cretaceous.	30. Ripley. 29. McNairy shell-bed. (Green sand; Rotten limestone.) 28. Coffee sand. (Eutaw.)
III. Paleozoic.	Carboniferous.	27. 26. 25. B. Coal Measures. Brushy Mountain measures. Tracy City measures. Bon Air measures.

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* The Elements of the Geology of Tennessee, prepared for the use of the schools of Tennessee. J. M. Safford and J. B. Killebrew, Nashville, Tennessee, 1900.

Table of the geological formations of Tennessee—Continued

Eras.	Periods.	Epochs.
III. Paleozoic.	Carboniferous.	A. Mississippian or Sub-Carboniferous. 24. Mountain limestone. 23. Saint Louis limestone. 22. Tullahoma formation. 21. Maury Green shale; Ball or Kidney phosphate.
	Devonian.	20. Black shale. (Chattanooga shale.) 19. Swan Creek phosphate. 18. Hardin sandstone. 17. Camden chert. (Oriskany.)
	Upper Silurian (or Silurian).	16. Linden limestone. (Lower Helderberg.) 15. Clifton limestone. (Niagara.) 14. Rockwood beds. (Clinton.) 13. White Oak Mountain sandstone. 12. Clinch Mountain sandstone. (Medina.) 11. Clinch Mountain Red shale.
	Lower Silurian (or Ordovician).	(*East Tennessee.*) 9 and 10. Sevier shale. Includes the following interpolated beds or lenses: (*c*) Upper red marble. (*b*) Crinoid bed. (*a*) "Iron" limestone. Knoxville marble. 8. Lenoir limestone. (*Middle and West Tennessee.*) 10*a*. Hudson. (College Hill; Cincinnati.) Hudson phosphate. 9*a*. Nashville. (Trenton.) (*g*) Stromatopora. (*f*) Cyrtodonta. (*e*) Ward. (*d*) Dove. (*c*) Capitol. Mount Pleasant phosphate. (*b*) Orthis. (*a*) Carter. (Black river.) 8*a*. Stones river. (Chazy.) (*d*) Lebanon. (*c*) Ridley. (*b*) Pierce. (*a*) Murfreesboro. (Central.) 7. Knox dolomite (upper part).
	Cambrian.	6. Knox dolomite (lower part). 5. Knox shale. } Coosa shale; Montevallo shale and sandstone. 4. Knox sandstone. 3. Chilhowee sandstone. (Weisner sandstone.)
II. Eozoic.	2. Ocoee. (Algonkian? Talladega.)	Partially crystalline, conglomerates, and slates.
II. Eozoic. and I. Azoic.	1. Crystallines.	Provisionally made to include: (*b*) Crystalline Ocoee and (*a*) True Archean. } Mica and other metamorphic schists. Gneisses, granites, syenites. Dikes of igneous rocks.

The name "Crystallines," suggested by Dr Eugene A. Smith, is used provisionally for the reason that the Tennessee Archean has not been satisfactorily separated from the crystalline Ocoee.

"Ocoee" was originally used by me * to include the mountain strata so grandly exposed in the gorge or canyon of the Ocoee river along its winding course of 12 to 13 miles through the Unaka mountain range. This appears to be a natural grouping, and I have seen as yet no justifiable reason for changing the name, so far, at least, as Tennessee and contiguous states are concerned.

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* Geology of Tennessee, 1869.

"Chilhowee sandstones" is an appropriate name and one which has stood a test of time. A few years since the idea was advanced that the sandstones and sandy shales of the Chilhowee mountain and its congeners were the offshore deposits of certain Upper Silurian formations; but it has been shown that this can not be the case. They may be offshore deposits, but are of far older date.

Very curiously, the name Chilhowee has been objected to on the ground that the formation has been called by several names; hence it was argued that Chilhowee ought to be dropped and another name taken. This procedure ignored the fact that the name Chilhowee had been used for the formation for many years before the others were even thought of. Furthermore, some of the names resulted from errors as to the age of formation. Briefly, the dropping of the name Chilhowee is not justified.

"Sevier shale" ought to be numbered 9, with perhaps the exception of its topmost part.

The name "Stones river" was used by me in a report published in 1856.* It was made to include certain bluish and dove colored limestones—in all, about 300 feet thick and outcropping chiefly along the course of Stones river,† in Rutherford county, Tennessee, and the lowest to be seen in the central part of the state.

It included also the Carter (Carter limestone) of the table. In my larger report of 1869‡ it was not used, the name "Lebanon" being substituted.

On the suggestion of Mr E. O. Ulrick, who had personally examined the limestones along the river and had carefully studied their fossils, both those acquired by him and those of my own cabinet, I restored my old name, "Stones river." In fact, Mr Ulrick had already made use of it in his writings. The name is especially appropriate to the geological and paleontological conditions present.

"Capitol, Mount Pleasant phosphate," is the *first* phosphate met with in ascending the Tennessee series of rocks.§

"Hudson, Hudson phosphate," is the *second* phosphate ascending.‖

"Camden chert" is a very fossiliferous chert, well characterized and a new member in the Tennessee series of formations, 50 to 100 feet in thickness.¶

"Hardin sandstone" is generally a fine grained, bituminous, grayish sandstone, locally running into the phosphate above it. It is a new member of the Tennessee series. In Hardin county it reaches a thickness of 12 to 15 feet.

The three formations—the Hardin sandstone, the Swan Creek phosphate, and the Black (Chattanooga) shale—are related. They are more or less phosphatic, abound in a small lingula, apparently the same in all, and, furthermore, are locally interbedded. Thin layers of the phosphate rock are seen at points interlaminated in the lower part of the Black shale.*

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*A Geological Reconnaissance of the State of Tennessee, Nashville, Tennessee, 1856, pp. 164.

† Stone's or Stones river, not "Stone river," as erroneously given in some histories. We ought to read, for example, the battle of Stones river, not of "Stone river." It is Stones river, so named in honor of a Mr Stone, one of the pioneers who first explored the section of Tennessee through which the lower part of Stones river runs, and not because it has a stony bed.

‡ Geology of Tennessee, Nashville, Tennessee, 1869, pp. 550, with plates.

§ See Elements, pp. 127, 128; also the American Geologist, vol. xviii, pp. 261–264, and other publications.

‖ See Elements, pp. 129, 130.

¶ See American Journal of Science, vol. vii, 1899, pp. 429–432.

In the "Swan Creek phosphate" we have another recently recognized member of the Tennessee geological column, and an interesting and important one. Its horizon is always indicated by the Black shale above and often by the Hardin sandstone below. It is the *third* phosphate rock.†

The "Maury Green shale" has importance as holding imbedded in it ball and kidney shaped concretions of phosphate rock. The concretions contain from 50 to 60 per cent of calcium phosphate. The shale has a thickness of from a few inches to 5 feet. The concretions make a *fourth* horizon of phosphate.

In the vicinity of Tullahoma, in the breaks of the flat highland on which Tullahoma is located, are beautiful waterfalls or cascades,‡ where may be seen good sections of a characteristic cherty limestone belonging to this division. Hence the name "Tullahoma limestone" was adopted. The same rock is seen in the bed of the stream at the edge of the town. At other points it has been thoroughly leached, the calcareous part being removed and layers or blocks of chert or shale left.

As a whole, the lower part of the sub-Carboniferous in Tennessee is markedly silicious. In the west we have a calcareo-silicious shale with chert (the Harpeth shale); then cherty limestone, leaving by weathering, masses of chert; and finally in the east sandstones and shales. These sandstones and shales have recently been referred to the Devonian under the name of the Grainger shale, but there is good reason for believing them to be sub-Carbonferous where they were originally placed.§

The name "Mountain limestone" for Tennessee and north Alabama is especially appropriate. It is the great formation of the base of the Cumberland mountains. Hence we have retained it.

The subdivisions of the Coal Measures given—the "Bon Air," the "Tracy City," and the "Brushy Mountain"—are in good part topographical and are intended for Tennessee students. Though an expedient, there is reason for this arrangement. The Cumberland mountains, speaking generally, are a great tableland. The flat rock of large areas of this tableland is the great conglomerate, recognized as such from Pennsylvania to Alabama, and which for local reasons I have named Sewanee conglomerate. This rock terminates the Bon Air measures above. Important coal beds and mines lie below it; among them the Bon Air mines; hence the name of the division.

Above this, terrace-like, rises the second division. It makes many second benches and upper, back smaller tables. This is likewise terminated above by a conglomerate. The division is from 250 to 500 feet thick and contains from three to five seams of coal, the most important of which, the name Sewanee, is extensively mined in the vicinity of Tracy City, the town giving name to the division.

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* It has been suggested that the Black shale is Mississippian (sub-Carboniferous); if so, then the Hardin sandstone and the Swan phosphate are most likely of the same age.

† See, further, Elements, p. 138; also the American Geologist, vol. xii, 1894, pp. 107–110, and other published accounts. In the Geologist a section is given embracing the formations above and below.

‡ At the base of the sections of the cascades may usually be seen the Maury Green shale, the Black shale, and the Swan Phosphate, all however, thin and poorly represented, especially the Green shale and the Phosphate.

§ Geology of Tennessee, Nashville, 1869, pp. 298–348.

The cap-rock of this division is recognized in the water gap of Big Emory near Harriman; hence a name I have given to it, the "Emory sandstone."[*]

The topography of the tableland which marks out the Bon Air and Tracy City divisions is more characteristic in the western portion, where the strata are horizontal or but little inclined, than in the eastern. In the eastern it is mostly obscured by the folds and displacements of the strata.

On the Tracy City divisions rests the Brushy Mountain measures, not much if any less than 2,000 feet in thickness, a great series of shales and sandstones, with very little limestone. These include not less than 14 coal horizons, half of which, or thereabouts, are coalbeds of workable thickness. The Brushy mountains are a great mass of mountain ridges, sharp crested, and reaching 1,400 to 1,800 feet above their bases. They are confined to the northeastern counties of the coal-fields.

These measures rest in turn, descending, on the Tracy City and Bon Air measures. A drill driven down vertically from one of the high peaks of the Brushy Mountain measures to the mountain limestone at the base of the entire coal series would pass through the strata of the three subdivisions for a distance of nearly 3,000 feet.

Middleton is a Tennessee name; hence the adoption of "Middleton-Clayton." Another name is Midway.[†]

The remaining formations explain themselves and need no comments.

HORIZONS OF PHOSPHATE ROCK IN TENNESSEE

BY JAMES M. SAFFORD

The object of this note is to point out the different horizons of phosphate rock observed in middle Tennessee. There are four of them, all of which are regularly stratified or are the residues after leaching of regularly stratified rocks. In addition, there is a fifth occurrence comprising irregular deposits, formed—travertine-like—by precipitation from solution.

The following enumeration and summary is in part from a small school book, "The Elements of the Geology of Tennessee:"[‡]

The Mount Pleasant, of Nashville or Trenton age, occurs over a wide extent of country; rock of high grade, mined cheaply in open excavations; production great and increasing.

The horizon of the Hudson, of the Hudson or College Hill age, is near or at the top of the Lower Silurian limestone and from 100 to 200 feet above the Mount Pleasant rock. Near and north of Nashville it is found at the tops of the hills; occurs in large quantities in Sumner county, also in Hickman county, occupying a lower topographical level, and, like the Mount Pleasant, mined in open excavations; production considerable and increasing.

The Swan creek, a division of the Devonian period, lies in the hills, like a bed of stone coal, and but little above the horizon of the Hudson—in fact, at Tottys bend, in Hickman. It rests on the Hudson. Westerly from this the Niagara limestone soon wedges in and separates the two. Mined for the most part like stone coal, by a system of tunnels and underground rooms.

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[*] See Elements, pp. 151.

[†] See vol. 1, Bulletins of American Paleontology, no. 4; The Midway Stage, by G. D. Harris, Cornell University, Ithaca, New York.

[‡] The Elements of the Geology of Tennessee, prepared for the use of the schools of Tennessee. J. M. Safford and J. B. Killebrew, Nashville, Tennessee, 1900, p. 142.

The imbedded phosphate concretions of the Maury Green shale make the fourth horizon. This is sub-Carboniferous, and lies at the base of that division and right above the Black shale. If the balls of phosphatic rock were mined in large quantities, it would be mostly by tunneling. They have been used but little, having been thrown out of consideration by the other abundant and superior phosphates.

Perry County phosphate, white and variegated in color, occurs in valleys in Perry county and belongs to no particular geological horizon, as its masses have been deposited from water on the rocks of several formations. Sometimes the Perry County phosphate presents itself in handsome marble-like pieces, not mixed with foreign matter; then again it is a medley of white mineral with broken chert. It occurs in large quantity and has been industriously quarried for market.

The age of the Mount Pleasant phosphate formation is easily shown to be Trenton or Nashville of the Lower Silurian. Its bed or the phosphate limestone from which it comes rests on what is known in Tennessee as the Orthis bed, so named for the reason that it is almost wholly composed of the valves of *Orthis testudinaria*.

The rock yielding the Mount Pleasant phosphate I have named "Capitol limestone," for the reason that it supplied the rock used in building the Tennessee capitol. It is a granular, bluish gray, current-formed rock, 25 feet thick, laminated by thin seams rich in phosphate alternating with seams of rock less so and lighter in color. The lamination is best seen on weathered surfaces. Its grains are mostly comminuted shells and corals. Often the rock is very rich in minute fossils (Cycloræ, Conodonts, etcetera). After the leaching, more or less perfectly, of the limestone there remained the available phosphate from 2 to 6 feet in thickness, rarely reaching 8 or 10 feet, and yielding from 70 to 82 per cent of calcium phosphate. It underlies some 6,000 or 7,000 acres, as estimated, is only covered by the soil, and is worked as an open quarry.

When the phosphatic limestone is covered by strata of rock, leaching does not take place, or but imperfectly: hence the leached product is found on the outcrop and covered only by the soil.

The Hudson phosphate comes from a phosphatic limestone which is much like the last named and like it suffers leaching. The phosphate is mined in open excavations. It ranges from 100 to 200 feet above the Mount Pleasant rock; contains *Cyclonema bilix*, *Pterinea demissa*, large *Orthis lynx*, *O. occidentalis*, *Strophomena alternata*, and minute shells and Conodonts.

Snow Creek phosphate is not a product of leaching, but a bed of phosphate. It is a dark rock, substantially, but weathers superficially to a yellowish gray, and then resembles sandstone, for which it has been mistaken. It contains the bones of large fishes, and also, like the other beds below it, multitudes of the shells of Cycloræ, Conodonts, etcetera.

Concretions of the Maury Green shales occur in places, crowded together in layers 18 to 20 inches in thickness. When rounded they look like so many closely packed, moderately sized cannon balls. They are, however, generally loosely scattered through the shale. They are wonderfully persistent, and can be found almost always in place above the Black shale, though usually of small size.*

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* For information as to the economic relations of the phosphates, see "Elements of the Geology of Tennessee," pp. 208–215.

After announcement of excursions in connection with Section E, American Association for the Advancement of Science, the Society adjourned.

Register of the Denver Meeting, 1901

The following Fellows were in attendance on the session of the Society:

E. R. Barbour.
J. C. Branner.
C. R. Dryer.
C. R. Eastman.
S. F. Emmons.
H. L. Fairchild.
H. T. Fuller.
U. S. Grant.
F. P. Gulliver.
E. O. Hovey.
A. C. Lawson.
J. R. Macfarlane.
W J McGee.
J. F. Newsom.
H. B. Patton.
F. W. Simonds.
W. G. Tight.
J. E. Todd.
C. R. Van Hise.
I. C. White.
S. W. Williston.
N. H. Winchell.

Present at the meeting of the Society, 22.

Fellow-elect

A. N. Winchell.

The following Fellows were in attendance on the meeting of Section E, American Association for the Advancement of Science:

H. F. Bain.
Samuel Calvin.
F. R. Carpenter.
T. C. Chamberlin.
F. W. Cragin.
A. H. Elftman.
R. S. Woodward.

Total attendance, 29.

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 13, PP. 17-26, PLS. 1-2 DECEMBER 28, 1901

STILL RIVERS OF WESTERN CONNECTICUT *

BY WILLIAM HERBERT HOBBS

(Presented before the Society August 27, 1901)

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CHARACTER OF THE DRAINAGE

The prevailing direction of streams within the state of Connecticut is southerly to southeasterly, in general correspondence with the slope of the Cretaceous plane of erosion. There are many small tributary streams which have northerly courses, but the most notable exceptions to the general rule are two streams which flow almost due north, and which, though separated by a distance of less than 25 miles, bear each the name Still river. The easternmost of these rivers is a tributary of the Farmington, while the other flows into the Housatonic. The name Still river is in both instances appropriate, for while the average fall of the normal streams of the region for the first 15 miles in their courses is about 70 feet to the mile, the Still river which is tributary to the Farmington falls but 100 feet in 10 miles, an average of 10 feet per mile, while that

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* For photographs illustrating this paper the author is indebted to Messrs H. L. Rogers, R. T. Sheldon, and H. Allen Smith.

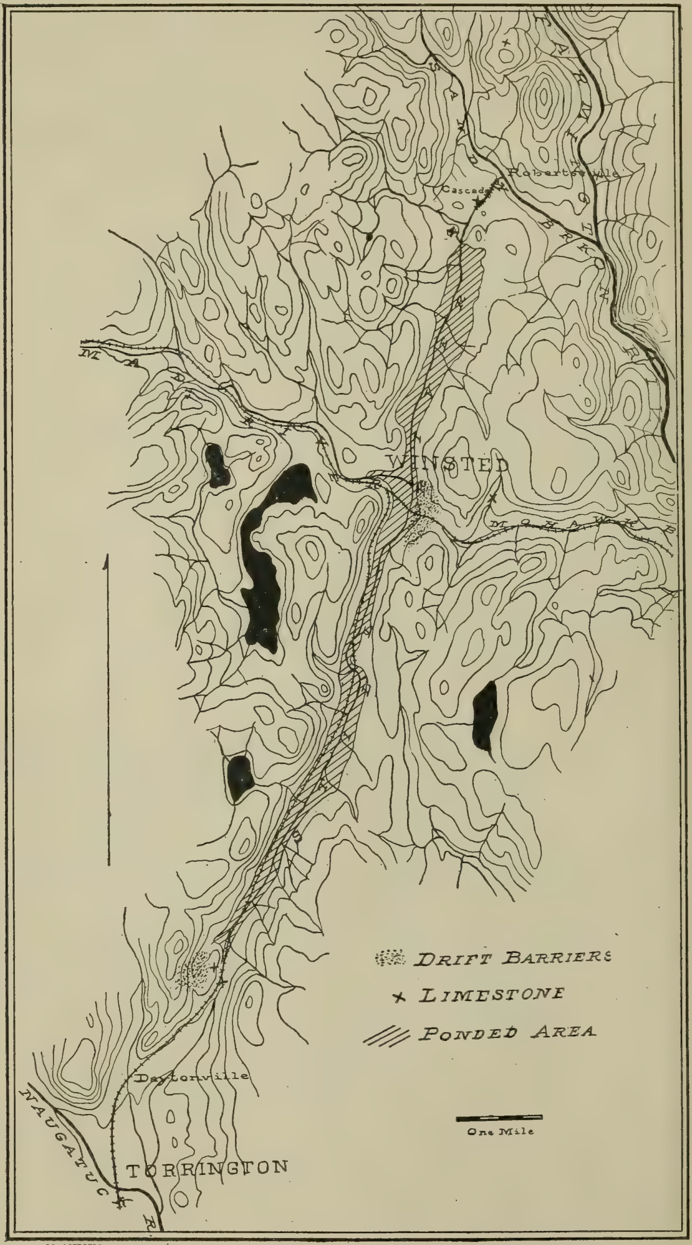
Robertsville
Cascade
WINSTED
MOHAWK B.
Daytonville
TORRINGTON
NAUGATUC R.
DRIFT BARRIERS
LIMESTONE
PONDED AREA
One Mile

FIGURE 1.—*Map of the (Farmington) Still River and Vicinity.*

tributary to the Housatonic falls 200 feet in 15 miles, or an average of 13 feet per mile.

Conditions affecting the Drainage generally

The orientation of the present drainage lying within the state of Connecticut is due to many different causes. Most important of these appear to be: (1) the slope of the plane of erosion, which is now being dissected; (2) the channels which remain as a legacy from the previous geologic cycle; (3) geologic structure planes; (4) the areal distribution of harder and softer rocks, and (5) the formation of drift barriers during the Glacial period. The first and the last mentioned conditions have had a larger or smaller influence upon the general direction of the streams, while the second, third, and fourth conditions have fixed more definitely the orientation of the stream channels. The importance of geologic structure planes in fixing the direction of drainage lines has, in the opinion of the writer, been very much underestimated by the modern school of physiographers. Its importance in the Connecticut region has been treated in another place* and need not be fully discussed here.

Rocks of the Region

The rocks of the region in which are the rivers here under consideration are gneisses and schists of Cambrian and pre-Cambrian age, with intrusive igneous masses and occasionally narrow belts of crystalline limestone or dolomite. As regards resistance to stream erosion, the chief differences are between the limestone on the one hand and the more resistant gneisses, schists, and igneous masses on the other. The two rivers present somewhat different conditions and should be considered separately.

The Still River Tributary to the Farmington

COURSE OF THE STREAM

As already mentioned, this stream has a course against the prevailing slope of the region. It takes its rise about 2 miles north of the city of Torrington, in a hardly perceptible divide separating its basin from that of the Naugatuck. Its course is north 30 degrees east for about 3 miles, then north 18 degrees to 20 degrees east, in a nearly straight line for about 7 miles, to a series of cascades, which in the succeeding and last mile of the river's course represent a total fall of about 100 feet. The stream empties at Robertsville into Sandy brook, one and one-half miles above the latter's junction with the Farmington. The Still meets the Sandy in a direction at right angles to its course. The pebbly bed of Sandy brook is here in striking contrast with the cascades by which the waters of the Still gain its level. For all save the extreme northern portion of its course, the Still river flows in a deep valley, the walls of which rise rather steeply 400 to 500 feet, though it is observed that the eastern slopes are less steep than the western. Near its outlet into Sandy brook this trough loses its distinctive characteristics.

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* The Newark system of the Pomperang valley, by William Herbert Hobbs, Twenty-first Ann. Rep. U. S. Geological Survey, part iii, 1899–1900, pp. 137–152: also The river system of Connecticut, by William Herbert Hobbs, Journal of Geology, vol. ix, 1901, pp. 469–484.

At Winsted, 4 miles above its outlet, the Still receives the waters of the boisterous Mad river, which, starting at Summit station in Norfolk, flows 8 miles in a deeply incised valley to the junction with the Still, during which flow it falls 600 feet, an average of 75 feet to the mile. The deeply incised valley of Mad river is prolonged beyond the junction with the Still by the similar valley of Mohawk brook, a direct tributary of the Farmington. The divide between the Still and the Mohawk is a low drift barrier, which closes the entrance to the latter from the former. The deeply cut valley troughs of the Still and of the Mad-Mohawk thus produce a nearly right cross, at the center of which is the city of Winsted.

CONDITIONS DETERMINING THE STREAM'S COURSE

There is an indication that the valley of the Still has been given its direction by a narrow belt of limestone inclosed between walls of gneiss. Of this belt only half a dozen scattered remnants are now to be found. Their positions are indicated on the map (figure 1) by the crosses. These narrow lenses, which are still preserved, are believed to represent the remnants of a trough infolded in the underlying gneiss. On this assumption these areas would formerly have been continuous and have formed a belt, the area of which at the beginning of the cycle may have been as large or larger than the present valley. Some indication of a second and parallel belt is perhaps afforded by the two small exposures of limestone farther to the east, the one about a mile east of Winsted and the other on the Ramsbottom place, approximately the same distance east of Robertsville.

The Mad-Mohawk valley takes the normal direction for a stream tributary to the Farmington. The valley of the Still is an extension of that of a small eastern tributary of the east branch of the Naugatuck, and its life history is best interpreted by assuming that the erosion of the Still valley was begun by the Naugatuck, which, working in the softer and more soluble dolomite, acquired an advantage over that branch of the Farmington which occupied the Mad-Mohawk valley.

The Naugatuck thus acquired more and more of the territory of the latter stream, until the trunk was tapped and the upper waters diverted to itself. The new stage of the river's history thus inaugurated, and also the conditions during the preceding stage, are illustrated by the second and the first diagrams respectively of figure 2.

The reversal of the drainage in the Still valley seems here to have been brought about by the drift obstructions thrown up during the Glacial period. Barriers of this kind have been observed at the present divides separating the Naugatuck and Mohawk drainages from that of the Still. The narrowing of the Still-Naugatuck valley north of Daytonville shows two channels separated by an island of gneiss. The western channel is filled with an accumulation of gravel and boulders, which partakes of the

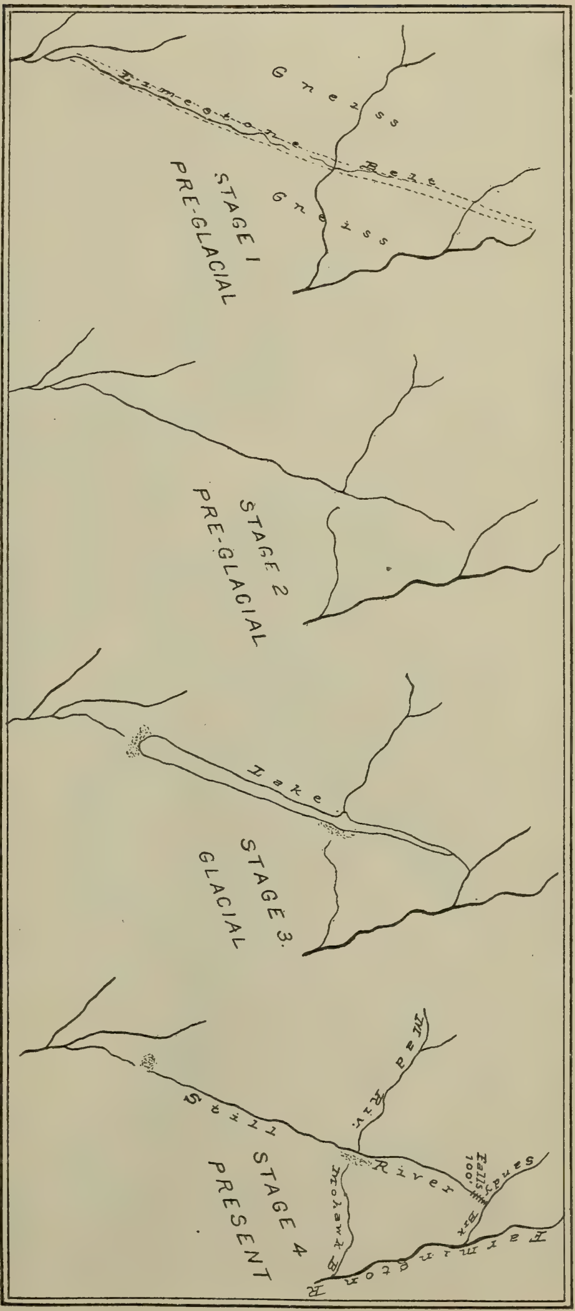

Gneiss
Limestone Belt
Gneiss
STAGE 1
PRE-GLACIAL
STAGE 2
PRE-GLACIAL
Lake
STAGE 3.
GLACIAL
Mad Riv.
Still River
Mohawk R
Falls 100'
Sand Brk
Farmington R
STAGE 4
PRESENT

FIGURE 2.—*Stages in the Development of the (Farmington) Still River.*

character of a "Bears den" moraine. This ridge rises to an elevation of about 160 feet above the bottom of the eastern channel, where runs the highway and both of the railroads connecting Winsted with Torrington, and where is the hardly perceptible present divide between the two river systems. Here is found a little of the uneroded limestone. It is therefore, highly probable that the Naugatuck was once dammed by an obstructing ridge of drift which completely choked both the east and the west channels at this point.

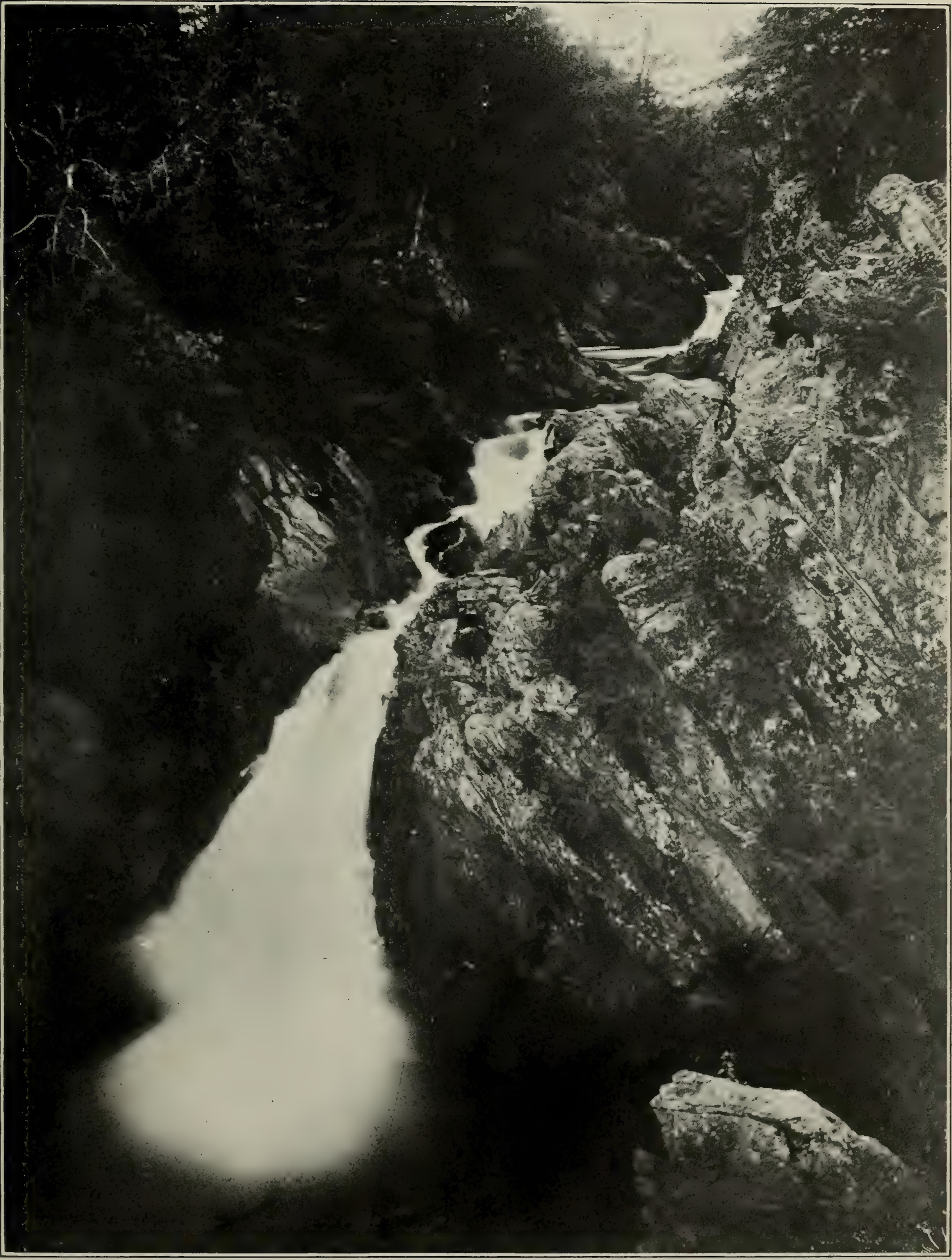
A second barrier of drift, which is still intact save where it has been pierced by the railway, closes the Mohawk valley to the waters of the Still. The summit of the obstructing ridge is about 45 feet above the present valley of the Still, in the same latitude. The effect of the damming near Daytonville, therefore, while it might discharge some of the impounded waters into the Farmington through the Mohawk by overtopping the obstruction, would extend the ponded area in the direction of Robertsville and also a small distance up the steeply ascending valley of the Mad. The top of the rock cut at Robertsville where the cascades begin in the discharge of the Still into the Sandy is, by aneroid measurements, 68 feet below the Winsted railroad station, which is at about the altitude of the top of the barrier which closes the Mohawk valley. This corresponds, then, to a fall of the river of about 23 feet in the 3 miles between Winsted and Robertsville falls. A new outlet for the impounded waters would, therefore, have been found over the steep wall at Robertsville into the Sandy, whose bed lies a full 100 feet below. Thus has doubtless been produced the beautiful series of cascades whose energy has been found so valuable in supplying the light for the city of Winsted. The third and fourth diagrams of figure 2 illustrate respectively the lake and the present stages of the river's history.

Plate 1 is a view of the upper cascade from a photograph taken before the construction of the dam and power plant.

The Still River Tributary to the Housatonic

COURSE OF THE STREAM

While the Still river of the Housatonic drainage area is believed to afford, like that just described, an instance of reversed drainage, the causes which have brought about the reversal are here by no means so clearly indicated. As shown upon figure 3, this sluggish stream flows from the city of Danbury in a direction about due north, and in a distance of about 18 miles from the headwaters of its eastern branch has a fall of about 200 feet—about 11 feet to the mile. It forms its junction



UPPER CASCADES OF (FARMINGTON) STILL RIVER

with the Housatonic in such a way that the downstream direction of the tributary is continued by the upstream direction of the master river.

CONDITIONS DETERMINING THE STREAM'S COURSE

Like the Still river of the vicinity of Winsted, geological conditions have here largely determined the courses of both the Still and the Housatonic. Throughout its course the Still and, above its junction with the Still, the Housatonic have their channels directed in strict conformity to the course of a belt of the Stockbridge limestone. On either side of the limestone belt rise dissected uplands of the harder gneisses, schists, and included igneous intrusive rocks. Near the junction of the Still with the Housatonic the contact of the harder and softer formations has been indicated on the map (figure 3), and it will be seen that the stream junction is at the contact on the eastern

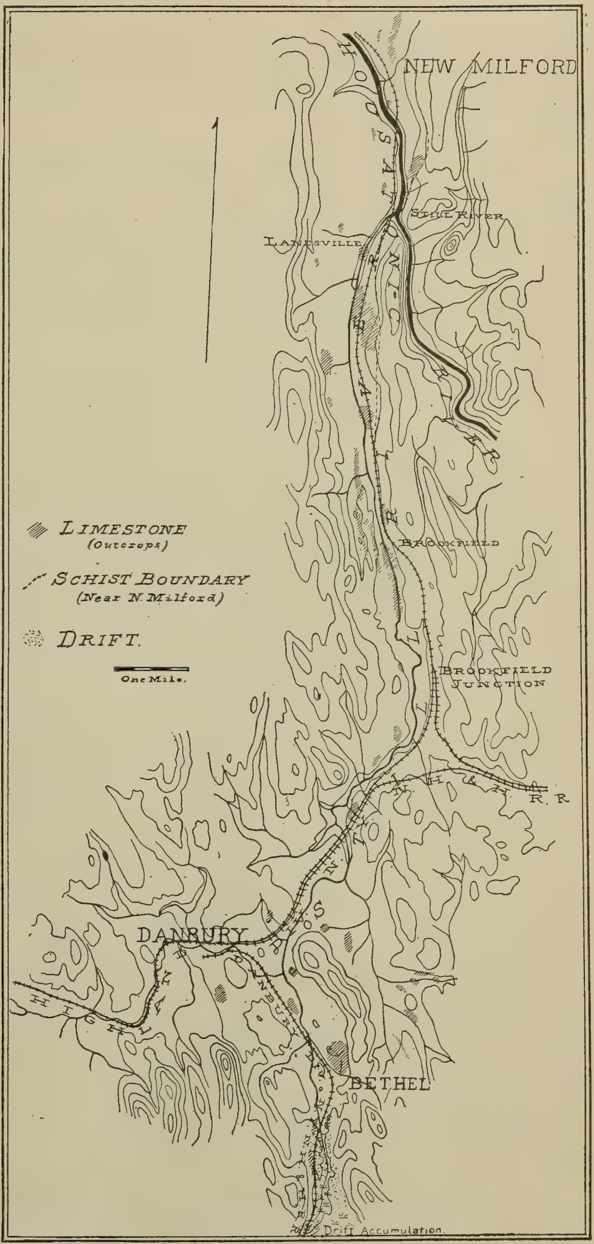

NEW MILFORD
STILL RIVER
LANESVILLE
BROOKFIELD
BROOKFIELD JUNCTION
N. Y. N. H. & H. R. R.
DANBURY
BETHEL
Drift Accumulation
LIMESTONE (Outcrops)
SCHIST BOUNDARY (Near N. Milford)
DRIFT.
One Mile.

FIGURE 3.—*Map of the (Housatonic) Still River and Vicinity.*

side of the limestone belt. The course of the Housatonic from this point across the uplands of harder rocks, despite the fact that the easier course to the sound is now apparent in the topography, introduces special difficulties of explanation.

THEORIES AS TO CERTAIN FEATURES OF DRAINAGE

Kümmel[*] has suggested the theory that the Housatonic is here a stream consequent upon post-Triassic tilting and faulting, the assumption being apparently that its channel, when conditions determined its present course, was still maintained by the river during the uplift of the land.

Crosby[†] has apparently adopted the same view for this and other excursions of the Housatonic into the gneiss uplands. While admitting the possible adequacy of this hypothesis, I am inclined to find the explanation rather in the influence of structural valleys in the harder rocks, taken in connection with that of obstructions formed during the Glacial period. The evidence seems to me to point strongly in the direction of an earlier course for the Housatonic through the valley of the Still to some other valley through which its waters reached the sound. In a paper[‡] read before this Society in June, 1900, I suggested this explanation and mentioned the Saugatuck river as one through whose valley the waters of the Housatonic may have been conducted to the sound. At about the same time Crosby[§] suggested that the waters of the Housatonic probably once flowed from near Merwinsville through the valley of the Swamp river into the Croton basin. That the valley of the Still was formerly occupied by a large stream is probable from its wide valley area.

As already stated, the structural valleys believed to be present in the crystalline rocks of the uplands due to post-Newark deformation may well have directed the course of the Housatonic after it had once deserted the limestone. The evidence for the existence of nearly vertical planes of dislocation and of the movement of included orographic blocks along them within the area of western Connecticut has been included in the author's papers above referred to.[||] It will suffice to state here that the principal elements of the river's zigzags within the gneiss belt agree closely with the well determined series of vertical fault planes character-

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[*] Henry B. Kümmel: Some rivers of Connecticut, Jour. Geol., vol. i, 1893, p. 381.

[†] W. O. Crosby: Notes on the geology of the sites of the proposed dams in the valleys of Housatonic and Ten-mile rivers, Technology Quarterly, vol. xiii, June, 1900, p. 121.

[‡] The present paper, which, slightly expanded, was read by title at the Denver meeting, August 27, 1901.

[§] Loc. cit.

Twenty-first Annual Report U. S. Geological Survey, 1899–1900, part iii, pp. 160.

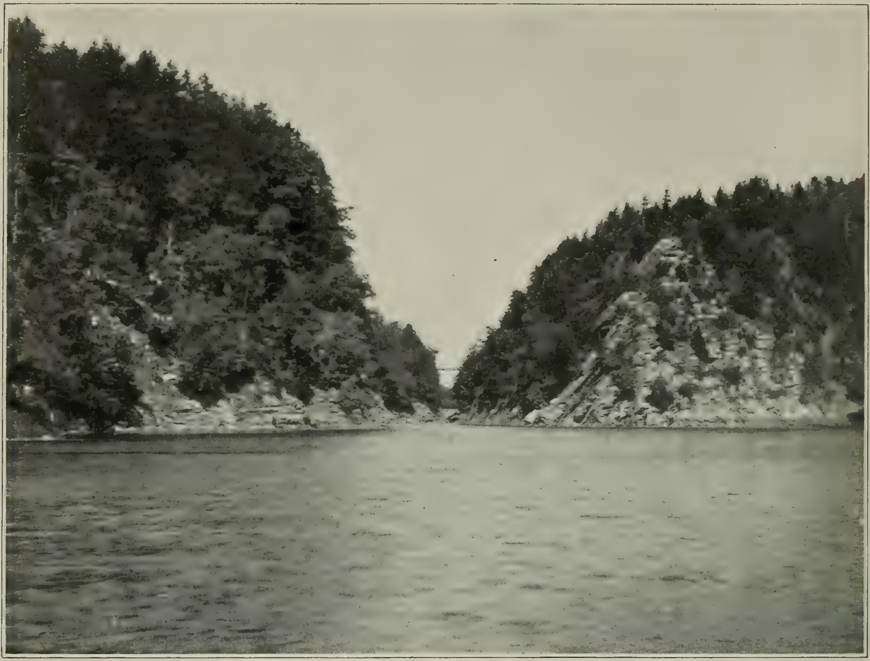


Figure 1.—Gorge of the Housatonic

The view looks northwest toward the bridge at Still river. The falls are visible in the distance

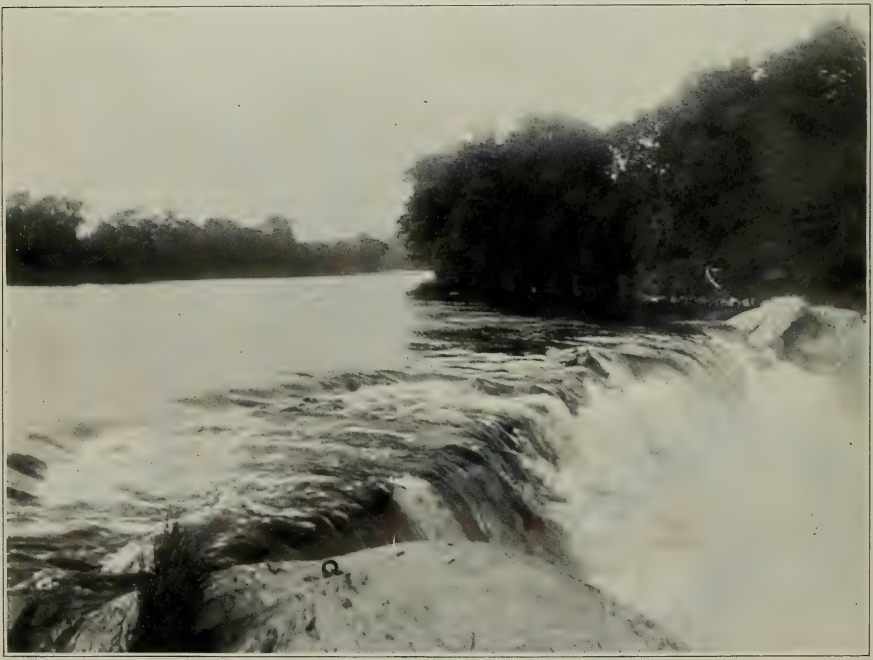


Figure 2.—Falls of the Housatonic where River enters Gorge in the Uplands

GORGE AND FALLS OF THE HOUSATONIC

izing the Pomperaug Valley area a few miles to the east. The deep gorge of the Housatonic (see plate 2, figure 1), through which the river enters the uplands not only crosses the first high ridge of gneiss in the rectilinear direction of one of the fault series, but its precipitous walls show the presence of minor planes of dislocation, along which the bottom of the valley appears to have been depressed

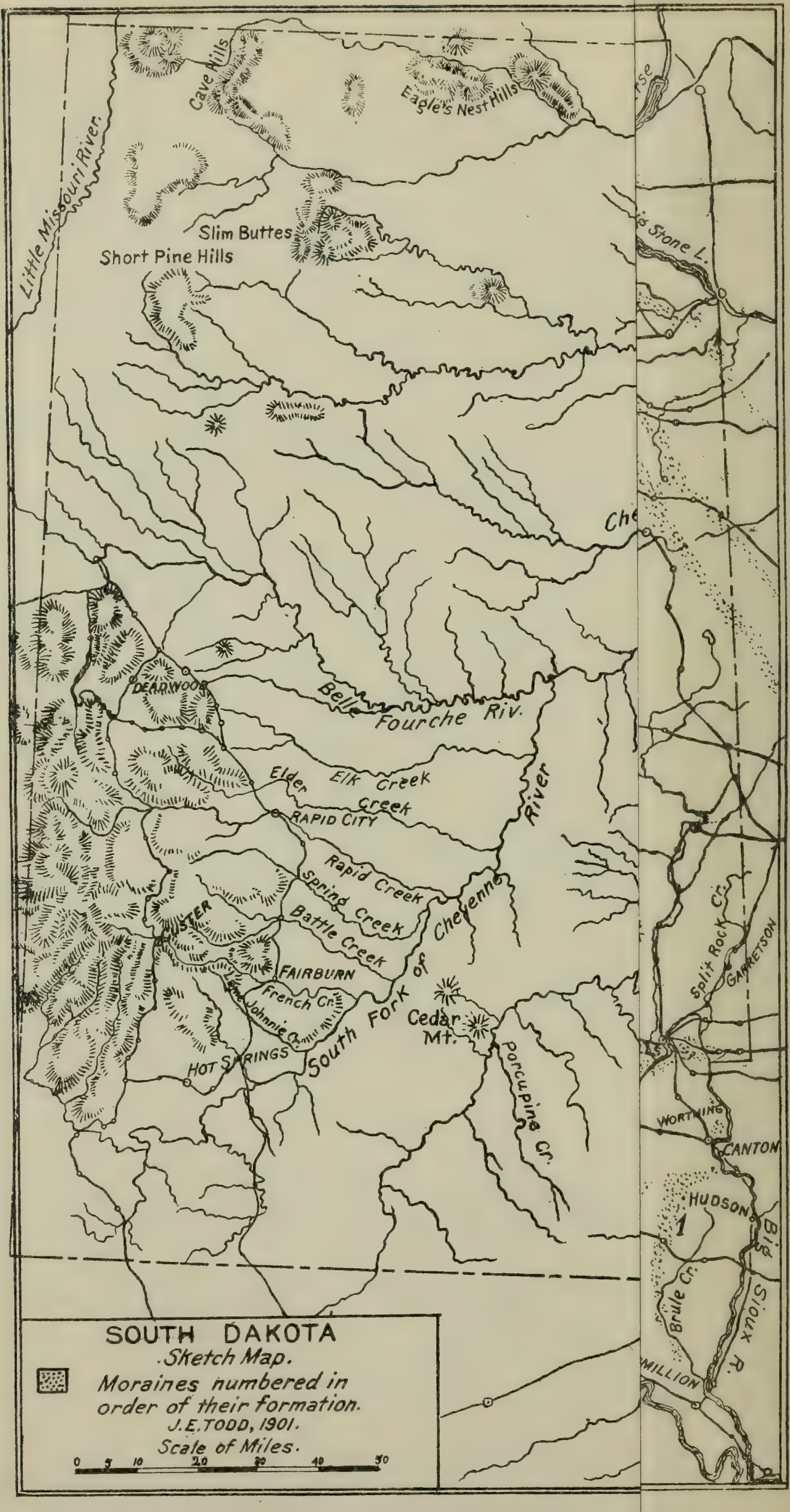
To turn the river from its course along the limestone valley some obstruction or differential uplift within the river basin may have been responsible. The former seems to be the more probable explanation in view of the large accumulations of drift material in the area south and west of Bethel and Danbury.

SOURCES OF THE STREAM

One of the present sources of the Still is in a high dam of glacial material which chokes the rock channel connecting the Bethel-Danbury valley with the valley of the Saugatuck. The belt of limestone continues through this well marked river cut to the village of West Redding. Another branch of the Still meets the Croton system at an almost imperceptible divide in the deep rock channel through which passes the Highland division of the New York, New Haven and Hartford railroad. The former discharge of the waters of the Housatonic through the Still into the Croton system, on the one hand, or into the Saugatuck, on the other, would require the assumption of extremely slight changes only in the rock channels which now connect them. In one case the Highland and in the other the Danbury division of the New York, New Haven and Hartford railroad has taken advantage of these possibly old channels.

The excursion of the Housatonic into the gneiss-schist area begins at Still River station by a fall of 8 to 10 feet over a shelf of the harder rock (see plate 2, figure 2). This fall may be explained if the channel of the former Housatonic were more deeply cut along the western margin of the gneiss area and an impounding of the water should raise its level to the top of the gneiss obstruction, and thus furnish an outlet through the fault gorge to the southeast. To assume that the Still river has not been reversed, but has taken its present course against the prevailing slope of the Cretaceous plain of erosion and wholly in consequence of the easy erosion in the belt of limestone, leaves many things to be explained.

The valley of the Still is much too wide to be explained by erosion of a stream of such small volume and slight declivity. The deep and wide rock channels connecting the branch basin of the Still with those of the Croton and Saugatuck require also an explanation. Again, the rock shelf at Still River station, over which the Housatonic falls, is less satisfactorily accounted for, although the formation of a *Graben* in the gneiss in post-Newark time is the hypothesis which is favored by the present writer in the explanation of the course of the Housatonic below this point. Detailed study over a considerably larger area than that which is here considered will be necessary before all the episodes in the history of the Housatonic can be adequately recorded.


Cave Hills
Eagle's Nest Hills
rse
Little Missouri River.
Slim Buttes
Short Pine Hills
Stone L.
Che
DEADWOOD
Belle Fourche Riv.
Elder
Elk Creek
Creek
RAPID CITY
Rapid Creek
Spring Creek
Battle Creek
CUSTER
FAIRBURN
French Cr.
Johnnie Cr.
HOT SPRINGS
South Fork of Cheyenne River
Cedar Mt.
Porcupine Cr.
Split Rock Cr.
GARRETSON
WORTHING
CANTON
HUDSON
1
Big Sioux R.
Brule Cr.
MILLION
SOUTH DAKOTA
Sketch Map.
Moraines numbered in order of their formation.
J.E.TODD, 1901.
Scale of Miles.
0 5 10 20 30 40 50

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 13 PP. 27-40, PL. 3 JANUARY, 28 1902

HYDROGRAPHIC HISTORY OF SOUTH DAKOTA

BY J. E. TODD

(Read before the Society August 27 ,1901)

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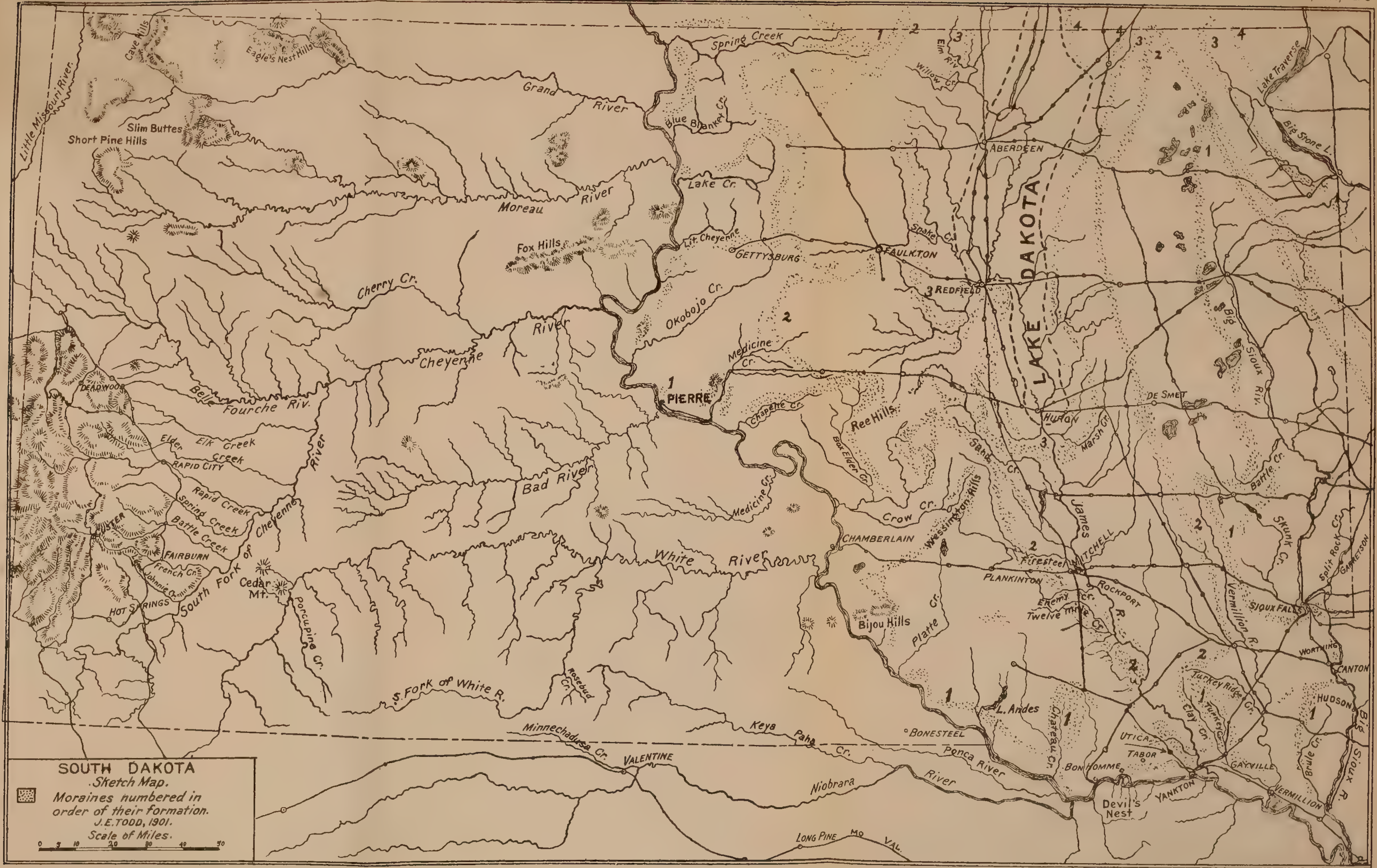
INTRODUCTION

This paper combines several conclusions which the writer has published elsewhere during the last decade, together with a few that are here presented for the first time, and is an attempt to set them forth as a consistent whole. In order to present a connected story, a few tentative conclusions and even mere guesses are introduced, but are distinctly marked as such. Nearly all the streams mentioned have been more or less personally examined.

OROGENIC MOVEMENTS BEFORE THE PLIOCENE

In the later Archean or pre-Cambrian there were evidently upheavals at both ends of the state; in the center of the Black hills and on the east an extension of land from Minnesota between Dell rapids and Sioux falls westward to the James river.

Of the early Paleozoic little need be said, except that there was evidently land in or near the Black hills, as is proved by the occurrence of


SOUTH DAKOTA
Sketch Map.
Moraines numbered in order of their formation.
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0 5 10 20 30 40 50
Little Missouri River
Cave Hills
Eagle's Nest Hills
Slim Buttes
Short Pine Hills
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Moreau River
Fox Hills
Cherry Cr.
Cheyenne River
Belle Fourche Riv.
Deadwood
Elder
Elk Creek
Creek
Rapid City
Rapid Creek
Spring Creek
Battle Creek
Custer
Fairburn
French Cr.
Johnnie Cr.
Hot Springs
South Fork of Cheyenne
River
Cedar Mt.
Porcupine Cr.
Bad River
White River
S. Fork of White R.
Rosebud Cr.
Minnechaduza Cr.
Valentine
Keya Paha Cr.
Niobrara River
Ponca River
Long Pine
Mo. Val.
Spring Creek
Blue Blanket Cr.
Lake Cr.
Lit. Cheyenne
Gettysburg
Okobojo Cr.
Medicine Cr.
Pierre
Chapelle Cr.
Ree Hills
Box Elder Cr.
Medicine Cr.
Crow Cr.
Wessington Hills
Chamberlain
Bijou Hills
Platte Cr.
Bonesteel
L. Andes
Choteau Cr.
Bon Homme
Devil's Nest
Utica
Tabor
Yankton
Gayville
Vermillion
Elm Riv.
Willow Cr.
Aberdeen
Snake Cr.
Faulkton
Redfield
Lake Dakota
Huron
Sand Cr.
Marsh Cr.
James
Mitchell
Firesteel
Plankinton
Enemy Cr.
Twelve Mile Cr.
Rockport
R.
Lake Traverse
Big Stone L.
Big Sioux Riv.
De Smet
Battle Cr.
Skunk Cr.
Split Rock Cr.
Garretson
Vermillion R.
Sioux Falls
Worthing
Canton
Hudson
Turkey Ridge Cr.
Clay Cr.
Turkey Cr.
Brule Cr.
Big Sioux R.
1
2
3
4

SKETCH MAP OF SOUTH DAKOTA, SHOWING MORAINES

quite large pebbles in the Potsdam sandstone. Probably the Archean core of the hills was land exposed to the attack of the sea and contributing largely to the material of that formation.

As Paleozoic time advanced, the western area gradually diminished, both by erosion and subsidence, while the eastern area, on the whole, increased several fold by gradual elevation.

An episode marked by the Silurian beds near Deadwood was a differential subsidence of the Black Hills region to the north, with a probable elevation on the south. The beds mentioned are found only around the north end of the hills.

Of the Devonian little is known. Thirty feet or more of green shales are doubtfully referred to that age, but no distinct break is found. During the Carboniferous a shallow sea surrounded the island, over which several feet of limestone were formed. Harney peak at that time, as we believe, was not wholly submerged.

With the close of the Paleozoic the sea began to retire from the Black hills, and probably continued the same movement around the eastern area. The extent in either case is not definitely known. As no Paleozoic beds have been recognized in the numerous wells which have been put down to crystalline bed rock east of the Missouri, it is doubtful whether the sea occupied that region during the Paleozoic and early Mesozoic. If it did at any time, all of the deposits there formed seem to have been completely removed.

The sea attained a minimum of extent in our state during the Triassic, if we read rightly the significance of the gypsiferous red clays barren of fossils; but with the beginning of the Jurassic began a steady gain. The gain seems to have been very rapid during the early part of the Dakota epoch, but the sea was quite shallow. This advance continued, probably, until the later part of the Niobrara stage of the Colorado. During the Fort Pierre epoch we may suppose it again retired, until at the opening of the Laramie it merely verged on our northern border. The evidence is that during that age the northern part of our State alternated between shallow seas and marshes with lakes. We have no distinct trace of the drainage of that epoch, unless it be in the Little Missouri and the upper part of the Belle Fourche; also in the upper courses of the streams draining the Black hills. We can easily believe that the drainage in the state elsewhere was generally toward the north, as we have indicated on the map.

The same general relation continued through the Eocene. The streams gradually deepened their valleys. This fact is attested by the eroded surface of the Montana below the Tertiary beds generally, and by deposits of gravel which are found under the Tertiary beds along French creek near Fairburn, along Battle creek and Lame Johnny creek, and doubtless at other points. Traces of these gravelly deposits are found below the Titanotherium beds along Indian draw and at other points.

During the Miocene, including the Oligocene, it has been commonly believed that a large freshwater lake crossed the state from north to south, east of the Black hills. This lake lay nearer the Black hills during the White River stage and shifted toward the east during the Loup Fork stage. Later investigations have made it certain that much of the material was deposited by rivers in their valleys and deltas, particularly in the vicinity of the Black hills. Some also have the idea that eolian deposits form a large portion of these beds. There can be little doubt, however, considering the topographic relations, that extensive lakes occupied much of the region, if not so extensively as formerly thought.

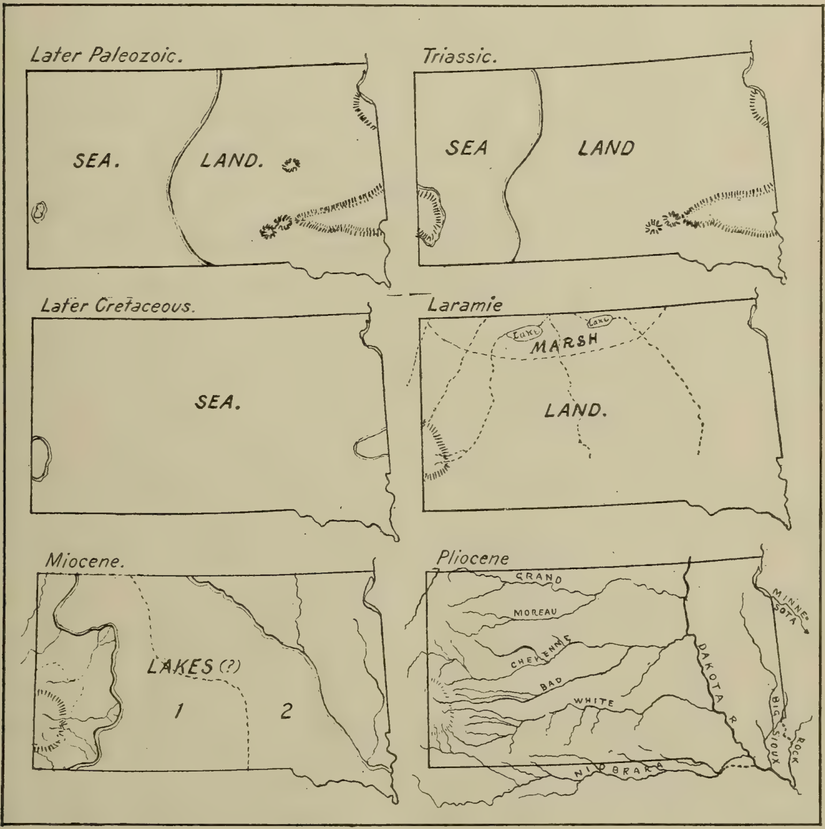
Later Paleozoic.
SEA.
LAND.
Triassic.
SEA
LAND
Later Cretaceous.
SEA.
Laramie
LAKE
LAKE
MARSH
LAND.
Miocene.
LAKES (?)
1
2
Pliocene
GRAND
MOREAU
CHEYENNE
BAD
WHITE
NIOBRARA
DAKOTA R
MINNESOTA
BIG SIOUX
ROCK

FIGURE 1.—*Hydrographic Conditions of South Dakota for the Epochs indicated.*

Traces of supposed wave action are not infrequently found.* The extensive deposit of fine material may have been deposited in lakes, as well as by atmospheric action, and the rarity of freshwater mollusks may be attributed to the muddy character of the waters.

While, therefore, the complete establishment of the earlier lacustrine view is not claimed, nevertheless by reason of the numerous marks of water action, the mapping has been done in accordance with that view.

That the Miocene deposits reached into the James River valley is inferred from the general slope and altitude of the deposits west of the Missouri and their identification at corresponding altitudes in the Ree hills and Bijou hills, and less certainly in the Wessington hills. It is possible that the Tertiary may not have extended much north of the Great Cheyenne river, except in the northwestern part of the state, where it is finely developed in the Slim buttes and Short Pine hills. In such a case the streams in the eastern part of the state probably flowed southwest into the Tertiary basin. Traces of deltas and other fluviatile deposits of the Oligocene epoch should be sought for under the eastern portion of the Loup Fork beds.

Movements in the Pliocene

OUTLINING OF EXISTING STREAMS

With the Pliocene we enter on surer ground and recognize the outlining of many of our existing streams. By this time lake Cheyenne, as King called it, had become filled and tilted, so as to drain toward the southeast. This we may attribute to the gradual rise of the Rocky Mountain axis. The same movement at an earlier stage would account for the shifting of the lakes toward the east during the Miocene. Streams that had begun in the Black hills as early as the Laramie had, during the Miocene, built their deltas across the lakes in spite of their shifting farther east, so as to form eastward courses for themselves, until they reached the bottom of the geosynclinal fold near the eastern edge of the Tertiary deposit. In this way our state simply shared in the movements common to the whole west side of the Missouri valley. The valley of the James in this state corresponded to the Missouri in Nebraska and Kansas.

PERSISTENT EASTWARD DRAINAGE

That the drainage was eastward across the present South branch of the Cheyenne is abundantly attested, first, by numerous erratics from the Black hills capping extensive areas in the valleys of the White river and Bad river; and, secondly, by traces of shallow channels crossing the divide.

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* Cf. Bulletin 2, South Dakota Geological Survey, p. 62.

The divide is strewn with pebbles and cobblestones generally at an altitude of 550 to 600 feet above the present Cheyenne,[*] in northern Ziebach county, and 350 to 400 feet above it fifty miles farther south, the difference being mainly due to the descent of that stream. "Cedar mountain," near White river, bears on its summit, 300 feet above that stream, near its junction with Porcupine creek, a heavy deposit of gravel and boulders of various crystalline rocks from the Black hills. Similar deposits of smaller size occur 150 miles due east of that point, capping terraces 500 to 600 feet above the Missouri, and near it a few miles south of White river in Lyman county. Pebbles of porphyry resembling varieties in the Black hills occur on the general upland level near Bonesteel, Gregory county. Similar crystalline erratics occur along the Niobrara as far east as Long Pine, and doubtless farther.

Some higher points in the Pine Ridge agency and along the divide between the White and Niobrara rivers are probably not strewn with these erratics.

Referring to the Pliocene map, we see all of these streams making their way eastward to the James River valley.[†] This feature is attested by the evidences of the change described in the next stage, and we only need to state here that the Bijou hills are clearly a continuation of the range of buttes, remnants of the old Miocene plain, which form an old divide between the White and Niobrara rivers. Moreover, this highland continues to a point south of Plankinton. So also the Tertiary beds in the Ree hills and Wessingtons, already alluded to, are evidently a continuation of the divide between the Bad and White rivers. So also Fox ridge west of the Missouri finds its continuation in the high ridge east of that stream from Gettysburg to Faulkton.

It should not be thought that the lines of these streams as represented on the Pliocene map should be found as buried channels, filled with drift, as is frequently the case with pre-Glacial streams in other parts of our country, for the baselevel for them all (except perhaps the Niobrara) was at a considerably higher level than in the present corresponding streams.

BEHEADING OF STREAMS FARTHER SOUTH BY THE CHEYENNE

At what time the South fork of the Cheyenne attained its present relations we are unable to say to a certainty. Possibly it may not have been before the early Pleistocene, but considering the erosion of the Cheyenne since that time and the height of the divide between it, and the headwaters of Bad and White rivers, it seems likely that the change was accomplished in the Pliocene.

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[*] Bulletin 2, South Dakota Geological Survey, p. 519, and Bulletin 1, South Dakota Geological Survey, p. 123.

[†] This conclusion was reached by the writer and published in 1884. Proc. Am. Assoc. Adv. Sci., vol. xxxiii, p. 391.

The reasons for the Cheyenne overreaching its fellows may be found in three conditions:

First, the greater rainfall in the northern hills. Though we may not understand the conditions which produce this at present, we see no reason why the same should not have existed in the Pliocene. This greater rainfall must have increased the erosion in the main portion of the stream and rapidly deepened it.

Second, the thinness of the Tertiary beds and the more easy erosion of the Montana beds underlying. Though the Tertiary beds have been mainly removed, it is probable that they extended to the Cheyenne in its middle course, and they certainly crossed it near the Black hills.

Third, the probable cutting back of the stream at an early date so as to capture the headwaters of a stream flowing north, possibly a branch of the Little Missouri and now the upper course of the Belle Fourche.

By the united influence of these conditions we can understand how the Cheyenne would outstrip its fellows in reaching baselevel. Moreover, the streams flowing eastward from the Black hills having their upper courses lying on the easily eroded Montana clays would have rapidly widened their valleys until the divides separating them would have been much narrowed if not completely broken at some points. In case of floods, which were probably more frequent at that time because of the gentler slope, overflows may have early extended into adjacent streams. In view of these relations it is not difficult to see how a tributary of the Cheyenne should cut back, along the line of junction between the Tertiary and the Montana, southward, nor is it difficult to believe that in a comparatively short time all the streams draining the Black hills were united in one system, as at present. This having been accomplished, the Cheyenne became the principal stream in size of valley and amount of water.

THE ANCIENT MINNECHADUSA

A few other less important particulars should be noticed. During the Pliocene it is likely that the south branch of White river, following the common easterly trend, entered the Niobrara through the Minnechadusa at Valentine. Though this channel has not been fully explored, it is known that from the abrupt bend in that stream there extends a broad valley toward the Minnechadusa, and above that point the South fork of the White river has a wide valley.* Moreover, between that point and the White river there are several miles of canyon in which there are falls. One is near the mouth of Rosebud creek.

Another peculiarity which should not be overlooked is that the Niobrara from its present mouth, after following the Missouri for 2 miles, turned to the left between Springfield and Bon Homme and made its way to James river by way of Tabor and Utica.

Another point is that the Big Sioux joined the Vermilion as indicated.

IN THE EARLY PLEISTOCENE

Under this head we would include all pre-Wisconsin Pleistocene time, for as yet the differentiation of the Kansan, Iowan, and other epochs has not been made for this region. What we have mapped may be considered as corresponding to the maximum extent of the ice during the Kansan stage. It will be seen that the streams are represented as flowing over the same channels as in the Pliocene, but that their size is increased. This we believe was true, owing to the drainage from the ice-sheet on the east, and also from an increased rainfall on the west, which we believe would be the logical results of the presence of the ice-sheet. Some may be surprised that the Kansan ice-sheet is not represented as occupying the James River valley, but such we believe was not the condition of affairs for the following reasons:

First, in the numerous borings in the James River valley no distinct evidences have been found of a lower till underlying that deposited by the Wisconsin ice-sheet.

Second, the new narrow course of the Missouri above Yankton evidently follows the margin of the ice-sheet which formed the Altamont or outer moraine, and the chances are strongly against an earlier sheet coinciding so closely in extent with that sheet, as must have been the case if the course of the river was determined by it. If it be suggested that the Kansan extended farther, we would reply that no traces have been found of a channel corresponding to it; and, on the other hand, if it be suggested with more reason that the Missouri for a time may have flowed in a channel which was obliterated or filled by the ice-sheet of the Wisconsin epoch, it is scarcely conceivable that such could have occurred without leaving some trace, at least where it crossed some of the unglaciated portions between the lobes of the ice-sheet of the Wisconsin epoch, and no such traces have been found. On the contrary, all seem to indicate that the Missouri was pushed out of the James River valley by the sheet of the Wisconsin epoch alone.

---

* Bulletin 2, South Dakota Geological Survey, p. 128.

If our conclusion is right, we may believe that the ice of the Kansan epoch, coming from the northeast into the Minnesota valley, was prevented, by the abruptness of its western side, the height and unbroken character of the plateau west of it, from entering the James River valley, although it succeeded in overriding the eastern edge and entering the valley of the Big Sioux. Glacial striæ in that valley are found in such relations as to indicate that it was occupied by a narrow lobe pushing down the Big Sioux, west of a small area, which is comparatively driftless, north of Garretson, South Dakota.

When the ice-sheet crowded against this plateau of the Coteau des Prairies the whole drainage from its western border farther north must have found its way over the divide between the James and Red rivers, we may suppose, at some lower and narrower portion, such as we may readily suppose, from the present conditions, may have been a little north of our state, as is represented on the map. There may have been first formed a temporary lake east of the ridge, and from it there must have been a rapid descent to the level of the James River valley. As the materials of the ridge were mostly clay and sand, such a barrier as that could not long resist the eroding influence of a stream which was fed by the draining from the whole western slope of the ice-sheet farther north. We can scarcely doubt that in a comparatively short time, it would cut down a canyon through this ridge to the level of the James river, which

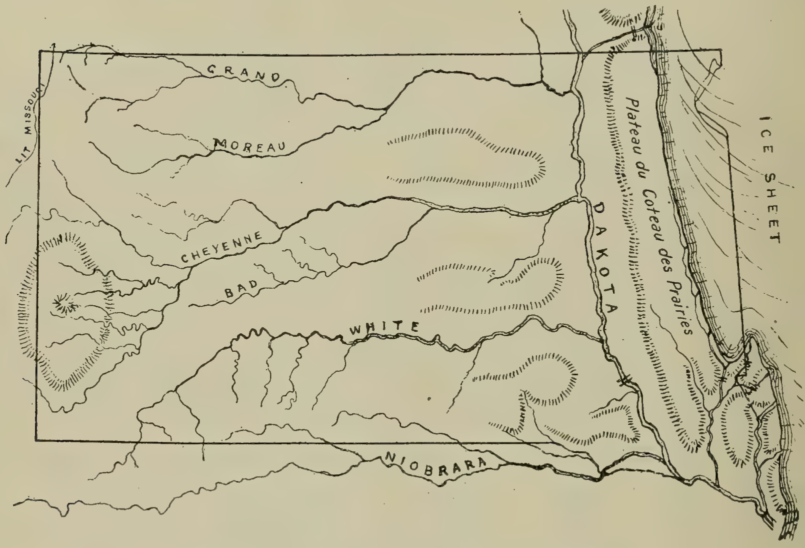

FIGURE 2.—*Hydrographic Conditions in South Dakota in pre-Wisconsin Pleistocene.*

in another epoch would be widened very considerably. Meanwhile the drainage from the edge of the ice farther south naturally found its outlet through the Big Sioux, which at that time we believe to have flowed southward into the Vermilion, and the Split Rock joined it in the northern part of Lincoln county.

The reasons for this supposition are found: (1) In the course of the ice-sheet in the next epoch, with the evident changes of drainage attending it; (2) in the fact that the level of the Big Sioux in its bend south of Sioux Falls is as high as the general surface 8 or 10 miles farther south; (3) in that topographic maps show a distinct sag across the present divide west of Worthing, South Dakota, leading to an ancient lake bed in Turner county connected with the Vermilion river.

During the early Pleistocene the streams were, no doubt, very active. Much of the James River valley was excavated at that time, though we may not suppose that it was as low as at present. The White river and Cheyenne show broad and high terraces about 200 feet above their present levels in the vicinity of the Missouri river. These may readily be believed to correspond to the level of these streams during the later Pliocene.

Another, terrace well marked and covered heavily with western gravel is found on White river 325 feet above the present level, and a similar terrace is found on the Cheyenne, near its mouth, 370 feet above the stream. These are believed to mark the level of the streams before the advent of the Wisconsin ice-sheet. If the country has been raised toward the west since the Pliocene we are unable to say what the gradient of those streams was during that epoch. If the altitude has not changed, the gradient from the late Pliocene terrace on White river to the present level of the James at Rockport would be about 4.7 feet a mile, allowing the usual crooks in the stream along the course indicated on the map, and the gradient for the early Pleistocene over the same course would be about 3.5 feet per mile, and from the mouth of the Cheyenne 2.6 feet, and 2, to the same point for corresponding times. If this is thought too great for the large streams which we have shown flowing over those channels, we may find recourse in presuming that the region west of this was not so much elevated at that time.

The streams radiating from the Black hills, like those about the Rocky mountains generally, have several prominent terraces, marking successive stages in the erosion of their valleys.

Rapid creek may be taken as a type. It exhibits at least three well marked terraces. The highest one noted in the hills is a broad one 450 feet above the present stream. This may correspond to the early Pliocene. Another is about 150 feet lower at the same point, which may correspond to the one 150 feet above the depot at Rapid City, and to one 200 feet above the junction of the stream with the Cheyenne. Another about 30 feet above the creek at Rapid City may be the one 100 feet above the stream at the junction. The second may date from the late Pliocene and the other from the early Pleistocene; but much more study is necessary before we can be sure of it.

The streams of the hills, as they deploy on the Cretaceous plain, very generally have shifted to the right, according to Ferrel's law, leaving their terraces more extended on the left side. There are, probably, a few cases of change of course by abstraction.

An important feature in James river at the present time is a broad sill of red quartzite at Rockport, in Hanson county. It is now 1,200 feet above sealevel, but before the erosion of the glacier was doubtless much higher. This no doubt long served as a barrier to the erosion of this valley. The ice-sheet was unable to remove it, though it carried away many thousand cubic yards and distributed it in the form of boulders farther south. From the depth of the till south of this barrier we find some reason for believing that there existed rapids at that point, as indicated on the map. If our view thus far has been correct, this ridge of quartzite exercised an important influence on the baselevel of James river and its tributaries above that point. Though the Niobrara river and Vermilion had evidently cut down to nearly their present depth before the deposition of the till in the southeastern part of the state, we find no trace of such deep channels having been formed in James river above Rockport or in any of the larger tributaries from the west above that point.

We may believe also that the Big Sioux descended by several rapids from its present altitude of 1,400 feet above the falls to the valley of the Vermilion, a little over 1,200 feet in altitude.

DURING THE LATER PLEISTOCENE

FORMATION OF THE MISSOURI

The early Wisconsin epoch witnessed a great change in the drainage of the state. The main cause was the advent of the ice-sheet from the northeast. If our reasoning hitherto has been correct, the overflow of water in the previous epoch opened the way for the entrance of the ice at this time.

The glacier rapidly filled the James River valley 1,000 to 2,000 feet in depth and as far south as Gayville. It flowed up the valleys of the

Grand, Cheyenne, and White rivers, filling up their valleys in that order for 100 miles or more. Of course this produced as many glacial lakes at first; at least, so in the first and third cases. The Cheyenne had formed a deeper and wider valley, and had perhaps so encroached in its southern divide that it found a low col by which it seems to have drained promptly into White river; at least there is not so clear evidence of a barrier there, nor of lacustrine action. This may have been due partly to the divide being mostly Fort Pierre clay, with little hard material in it.

In the valley of Grand river, however, a large temporary lake was formed, which has been called lake Arikaree.* This is attested by a shoreline lying on the north slope of Fox ridge,† by the distribution of northern boulders over its bed, and more clearly by traces of an old channel 400 feet higher than the present Missouri and east of it in northern Potter county.‡ By this means it drained by way of the Little Cheyenne into the Cheyenne. We may suppose that there was another outlet, which, cutting more rapidly, became the present Missouri at that point.

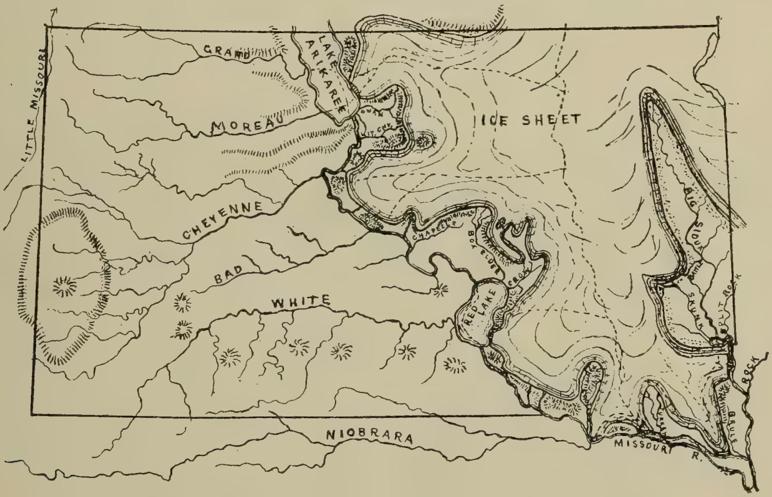
GRAND
LAKE ARIKAREE
LITTLE MISSOURI
MOREAU
CHEYENNE
BAD
WHITE
ICE SHEET
CHAPELLE
BOX ELDER
CROW
RED LAKE
BIG SIOUX
SPLIT ROCK
ROCK
BRULE
NIOBRARA
MISSOURI R.

FIGURE 3.—*Hydrographic Conditions in South Dakota in early Wisconsin Epoch.*

In the valley of White river another lake was formed north of the high divide of which the Bijou hills are a remnant. The evidence also in this case is the distribution of boulders and trace of the upper limit of drift like a water line around the Bijou hills and south of the mouth of White river, west of the Missouri, about 590 feet above the Missouri or 1,880 above the sea;* also evidences of a series of rapids marked by vast accumulations of boulders above the mouth of Platte creek and the canyon-like character of the trough of the Missouri at the Bijou hills, though these are less conclusive.

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* Bulletin 1, South Dakota Geological Survey, p. 140.

† Ibid., p. 119.

‡ Figured, Bulletin no. 144, U. S. Geological Survey, pl. xi.

It seems not improbable that because the Grand and Cheyenne rivers were dammed before the White, and because the ice did not reach its maximum extent until some time after it had dammed the White, that meanwhile there may have been a waterway over the lower land east of the Bijou hills, past lake Andes and Choteau creek to the Niobrara; but, if so, it was not occupied long enough to excavate much of a trough.

DISPLACEMENT OF THE NIOBRARA

The ice-sheet flowed over a sag in the divide between the James and the Niobrara into the valley of the latter stream so as to fill it from Bon Homme to the vicinity of Yankton, forcing that stream, reinforced by contingents farther north, to cut a new channel between Bon Homme and Yankton. This may partly explain the present rugged character of the region known as the "Devil's nest," in Knox county, Nebraska.

DIVERSION OF THE BIG SIOUX

Again, on the east of the main valley the divide between the James and the Vermilion, perhaps attenuated by the latter receiving during the preceding epoch the copious drainage of the ice-flow, was also overridden, and the ice filled its valley to the vicinity of Vermilion. This so dammed the Big Sioux, which was a tributary of the Vermilion, that another small lake was formed over the present site of Sioux Falls. This found an outlet into the Split Rock and eventually around the edge of the ice into Rock river, near the present town of Hudson, South Dakota.

The evidences of such changes, besides those already mentioned, as indicating the former course of the Big Sioux are the fluvio-lacustrine beds about Sioux Falls, including some aqueous till, old soils and silts, and the canyon-like character of the Big Sioux between Canton and Hudson, South Dakota.†

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* Bulletin no. 158, U. S. Geological Survey, p. 47.

† Compare the author's paper, American Geologist, vol. xxv, p. 96. Further examination has, however, renewed a former conclusion as given above. Some of the evidence is given. Bulletin no. 158, U. S. Geological Survey, pp. 102, 103.

The lowering of the divides so as to allow the ice to transgress them and the extent of the ice in these lateral valleys toward the south afford further evidence that they were lower south of the quartzite ridge, as we have before suggested and as is indicated on the map for the early Pleistocene.

PERIPHERAL AND INTERLOBULAR STREAMS

Such were the changes accomplished, when the ice was reaching and occupying the First or Altamont moraine. At the same time several minor streams were established, or at least much enlarged and deepened. These may be grouped in two classes, those which flowed parallel with the edge of the ice, usually just outside of the moraine, which we may call *peripheral*, and those originating between two adjacent lobes of ice, which we may call *interlobular*.

Of the former class there are (passing around the ice from east to west) Battle creek, Brule creek, Box Elder creek, Chapelle creek, Little Cheyenne creek, and lower Swan Lake creek.

Of the latter class, in similar order, upper Big Sioux, upper Skunk creek, Turkey creek, upper Crow creek, the upper Box Elder, the lower Medicine creek, and the upper part of Swan Lake creek. These are marked on the map.

Similar streams of less importance, particularly of the first class, were developed in connection with the formation of the later moraines. Of these we may name, for the Second or Gary moraine, the upper Vermilion, Turkey Ridge creek, Clay creek, and the Firesteel-Enemy-Twelvemile creek, which combined the upper courses of these several streams of the present time. It also had several successive courses shifting to the northeast as the ice receded; also Medicine creek, the Blue Blanket, and Spring creek.

And for the third or Antelope moraine, Marsh creek, Sand creek, upper Snake creek, and portions of Willow and Elm creeks.

An interesting incident of the recession of the ice-sheet of the Wisconsin epoch was the gradual formation of a shallow lake which has been named lake Dakota. It extended from the vicinity of Huron past Redfield and Aberdeen to Oakes, North Dakota. Its greatest extent was probably when the ice occupied the fourth moraine. It was filled quite evenly with fine silt. Smaller lakes continued the series to Mitchell and the red quartzite sill before mentioned at Rockport. Its primary cause may be found in the greater erosion of the clays by the glacier north of that sill.*

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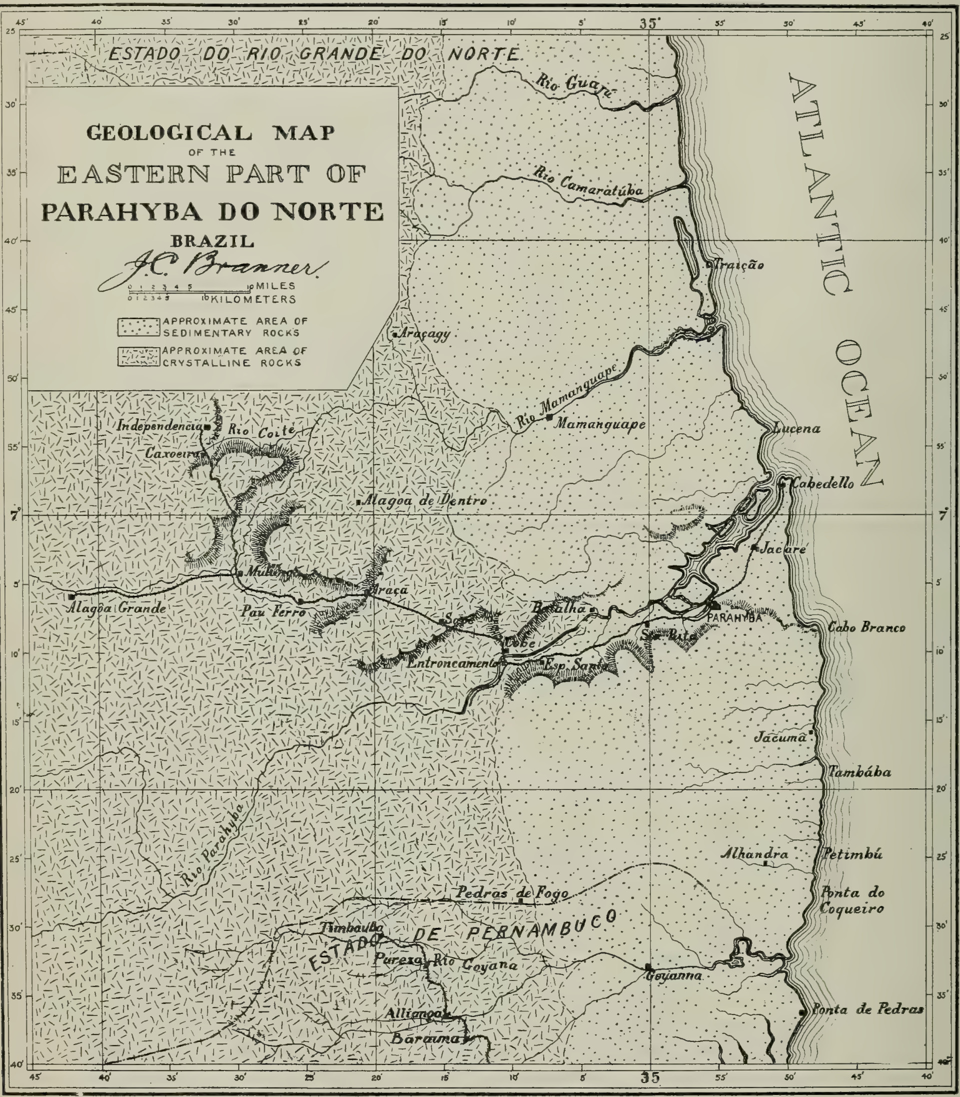
* Bulletin no. 144, U. S. Geological Survey, p. 52.

Thus we have found the history very interesting, even in outline. When further research shall have gathered up the details it will doubtless become much more so. The region around the Black hills and about the margin of the drift may prove to be the most instructive areas for research. We may hope thereby to correlate, more satisfactorily than has been done, the movements of the ice-sheet with the history of the Rocky Mountain axis. We may hope also for further light on the relations of the loess to both.


GEOLOGICAL MAP
OF THE
EASTERN PART OF
PARAHYBA DO NORTE
BRAZIL
J.C. Branner
MILES
KILOMETERS
APPROXIMATE AREA OF SEDIMENTARY ROCKS
APPROXIMATE AREA OF CRYSTALLINE ROCKS
ESTADO DO RIO GRANDE DO NORTE
ATLANTIC OCEAN
Rio Guajú
Rio Camaratúba
Traição
Araçagy
Rio Mamanguape
Mamanguape
Lucena
Cabedello
Independencia
Rio Coité
Caxoeira
Alagoa de Dentro
Jacaré
Mulungú
Alagôa Grande
Pau Ferro
Araçá
Sapé
Batalha
PARAHYBA
Cabo Branco
Cobé
S. Rita
Entroncamento
Esp. Santo
Jacumã
Tambába
Rio Parahyba
Alhandra
Petimbú
Pedras de Fogo
Ponta do Coqueiro
Timbaúba
ESTADO DE PERNAMBUCO
Pureza
Rio Goyana
Goyanna
Alliança
Baraúnas
Ponta de Pedras
35°
7°

GEOLOGICAL MAP OF THE EASTERN PART OF THE STATE OF PARAHYBA DO NORTE

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
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GEOLOGY OF THE NORTHEAST COAST OF BRAZIL

BY JOHN C. BRANNER

(Presented before the Society August 27, 1901)

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INTRODUCTION

So little is known of the geology of northeastern Brazil that no apology is needed for the obvious imperfections of the present paper. Most of the notes were taken during a trip along the coast and several trips across the sedimentary beds in 1899, but I was previously somewhat familiar with the geology of the region through my work there while a member of the Geological Survey of the Empire (the Commissão Geologica do Brazil), and from subsequent trips to the interior of Pernambuco. Fortunately I have been able also to obtain valuable contributions from several correspondents whose names are mentioned in the paper to supplement my own observations.

GEOLOGY OF THE STATE OF PARAHYBA DO NORTE

RESULTS OF PREVIOUS AND PRESENT INVESTIGATIONS

Aside from the very brief references cited beyond, the only paper ever published on the geology of the state of Parahyba do Norte is that of E. Williamson.* Mr Williamson says the rocks of that state are Tertiary, Cretaceous, and Laurentian, but he mentions no paleontological reasons for these divisions. So far as the Tertiary and Cretaceous divisions are concerned, Mr Williamson's classification seems to be correct, as will presently appear.

Although I have visited Parahyba several times, the trips have been hurried, and it has never been possible for me to make a careful search for fossils. Since my last visit, in 1899, however, Mr H. G. Sumner, superintendent of the Conde d'Eu railway, has secured and kindly sent me a few fossils recently found in quarries at the base of the hills near the railway station at that city. These fossils are of great importance and interest, for they are the first and only ones thus far found which throw a decided light on the geologic age of the beds at and about

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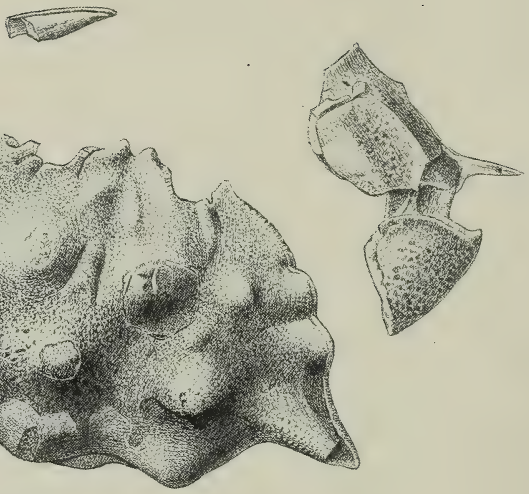
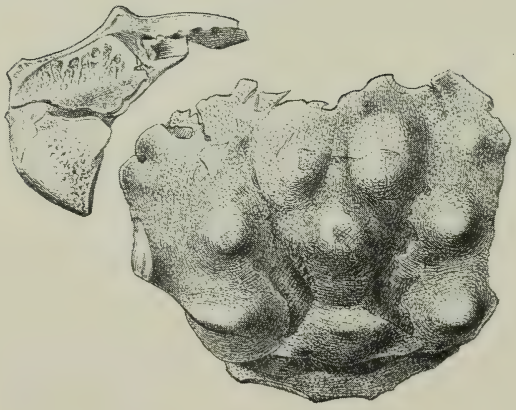
* This paper was read in April, 1867, before the Geological Society of Manchester, England, and published in its Transactions, vol. vi, pp. 113–122, under the title "Geology of Parahiba and Pernambuco gold regions."





ZANTHOPSIS CRETACEA RATHBUN SP. NOV. FROM PARAHYBA DO NORTE

Parahyba.* They consist of some teeth and fragments of bones of a fish, portions of the carapaces of two crabs, and one somewhat crushed cephalopod. The cephalopod, Dr J. P. Smith † tells me, is a species of *Sphenodiscus*, one of the so-called "Ceratites," and of positive Cretaceous age.

MISS RATHBUN'S DESCRIPTION OF ZANTHOPSIS CRETACEA

The crabs were submitted to Miss Mary J. Rathbun, of the Smithsonian Institution, and she has kindly furnished the following description:

Zanthopsis, *McCoy*

Zanthopsis, McCoy, Ann. Mag. Nat. Hist. (2), iv, 162, 1849. *Zanthopsis cretacea*, Rathbun, sp. nov.

Carapace about one and three-fourths times as wide as long. Surface densely granulate, posterior portion punctate; regions fairly well delimited. Six prominent nodules: two median, one occupying the greater part of the mesogastric region, one surmounting the cardiac region; the other four are branchial, the anterior pair in line with the gastric nodule, the posterior pair a little in front of the cardiac nodule and a little outside the anterior pair; these last are high and subconical; the posterior pair are lower and broader than long. Four less conspicuous nodules also exist—one on each protogastric lobe, one on each hepatic area. A long, low protuberance lies behind each lobe of the front. The grooves on either side of the narrow mesogastric region are rather deep.

The width between the outer angles of the orbits is a little less than one-third the width of the carapace; the front occupies nearly half the space; it is produced and divided by a median V-shaped notch into two lobes, with oblique margins, forming a triangular tooth at the inner end, and a right angle at the orbital end. The orbits are directed forward; their margins show two fissures, separated by a narrow, non-projecting lobe; the outer angle is a little more advanced than the outer angle of the front.

The long antero-lateral margin bears at its middle two somewhat dentiform, upturned lobes, defined on either side by deep grooves. Between these lobes and the orbit, the antero-lateral margin is nearly straight; behind the lobes, the margin forms the anterior border of a long, stout spine occupying the lateral angle of the carapace. Postero-lateral margin concave. Posterior margin not distinguishable.

The only appendages preserved are, in the larger specimen, a portion of the right cheliped (carpus and palmar portion of propodus), and a fragment of the left dac-

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* Hartt mentions estherians found by Agassiz in certain green shales at Parahyba, from which he, Hartt, infers that the beds are of fresh-water origin and equivalent to those of Bahia. C. F. Hartt: "Geology and Physical Geography of Brazil," p. 445.

These fossils, however, were never identified, and as estherians are not necessarily of fresh-water origin, and inasmuch as the cephalopod shows that the deposits are marine, the correlation must be regarded as unwarranted. Capanema says of a visit to Parahyba: "A badly preserved crinoid leads me to suppose that the rock belongs to the Cretaceous," an equally hasty conclusion. Trabalhos da Commissão Scientifica de Exploração, I, Secção Geologica, p. cxxii, Rio de Janeiro, 1862.

† Professor of paleontology in Stanford University.

tylus; in the smaller specimen, the carpus and propodus of the left cheliped. Upper surface of these two segments reticulated. Dorsal face of carpus subtriangular, the distal margin being a little longer than the other two. The palm is nearly one and a half times as long as wide and a little longer than the fingers; a blunt longitudinal carina runs along its outer third; outer margin furnished with a long slender spine near its proximal end and a thick rounded lobe opposite the base of the fingers. Outer margin of propodal finger rimmed. Judging from the socket of the movable finger, it lies above and overlaps the immovable one; the latter is provided with a median dentated ridge which may have served as a cutting edge against that of the overlying dactylus.

The length of larger specimen from median frontal sinus to rear of cardiac region is 34 millimeters; length from tips of frontal teeth to same point, 35.3 millimeters; width of carapace (approximate), 67.2 millimeters; width between outer orbital angles, 22 millimeters; width of front, 10.5 millimeters.

The type locality is the quarry at the base of the hill in the city of Parahyba do Norte, Brazil; two specimens.

The genus *Zanthopsis* contains several species described from the Eocene of Europe. *Z. cretacea* differs from them all in the character of the nodulation. It resembles *Z. kressenbergensis*, Meyer, in having a long lateral spine, but this spine is much stouter in our species. The long spine on the propodus of the cheliped is unique. Specimens are in the National Museum of an undescribed species of *Zanthopsis* from the Eocene of Alabama.

The specimens here described are deposited in the U. S. National Museum at Washington, D. C.

DOCTOR WILLISTON'S DESCRIPTION OF CIMOLICHTHYS N. SP.

The fish remains from Parahyba do Norte, Brazil, have been referred for determination to Dr S. W. Williston, of the University of Kansas, who kindly furnishes the following description:

"The specimen of *Cimolichthys* preserved is a fragment of the skull, contained in a small block of rather hard limestone. The only characteristic portion is a part of the right dentary, 65 millimeters in length, containing five teeth of the inner row and eight or ten of the outer row. This portion, however, is so characteristic of this peculiar genus of Cretaceous fishes that there would seem to be little doubt of the affinities of the specimen, incomplete as it is. It can be referred almost unhesitatingly to the genus *Cimolichthys* (*Empo*), an opinion concurred in by Mr Steward, who has studied our Cretaceous fishes and who has examined the present specimen. The material, however, is hardly sufficient to render the specific determination certain, should the beds whence the specimen comes yield other species of the same genus upon further examination. For this reason I refrain from giving the present species a name.

"*Cimolichthys* has been known hitherto only from the Upper Cretaceous of Europe and North America. The type of the genus, *C. lewesiensis*, is from the Upper Chalk of England, while isolated teeth have been referred to the genus coming from the upper Pläner beds of Bohemia. In North America four or five species are known from the Niobrara and Fort Pierre Cretaceous of Kansas. It would seem highly probable, therefore, that the horizon of the present species is in the upper part of the Upper Cretaceous.

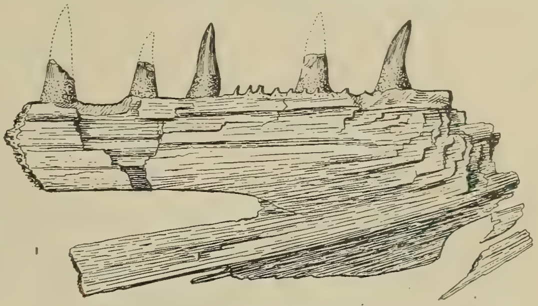

FIGURE 1.—*Right Dentary of Cimolichthys n. sp.* Natural size.

"The genus is characterized by the dentition, especially of the palatines and dentaries. In the present specimen the two rows of teeth situated upon the dentary have a great resemblance to those of the American species, especially *C. naepiolica.* The inner row of large teeth have the characteristic compressed form with anterior and posterior cutting edges placed somewhat obliquely. They are unstriated. The base is much elevated and conical, and the five teeth preserved are nearly all of the same size, with only slight discrepancies in the intervals between them. The outer teeth appear to be in a single row. They are small and tuberculiform, about one millimeter in height, and with intervals between them of about the same. The surface of the dentary has been mostly destroyed.

	Millimeters.
"Space occupied by five inner teeth	55
Height of middle tooth above bone	12
Height of base	4
Width of tooth where joined to base	4
Space occupied by eight teeth of outer row	10"

AGE AND ANALYSIS OF PARAHYBA LIMESTONE

The chief point of interest in this small collection of fossils is that it settles definitely the Cretaceous age of the leaden gray limestone at the base of the hills about the city of Parahyba.

A specimen of the rock containing the fossils was analyzed in duplicate and found to be fairly good limestone.

Analysis of the Cretaceous Limestone from Parahyba do Norte

	Per cent
Silica (SiO_2)	7.32
Iron (FeO)	1.26
Lime (CaO)	45.82
Magnesia (MgO)	3.95
Carbon dioxide (CO_2)	41.48
Sulphuric acid (SO_3)	0.44
Total	100.27

This rock was examined under the microscope in the expectation of finding microscopic organic remains, but no fossils were found.

The strata forming the higher parts of the hills appear to rest conformably on these lower marly beds, but the upper beds have yielded no fossils.

COASTAL SEDIMENTS

Mr Sumner's house, on top of the hills south of the governor's palace, in the city of Parahyba, has an elevation of 46 meters above tide-level. A well was dug here 28 meters deep; it penetrates only the pink, red, and mottled sands and clays characteristic of the coastal sediments. Many white quartz pebbles the size of a hen's egg and more or less white kaolin were found in the earth taken from this well. The section seems to resemble closely that exposed in the bluffs at Cabo Branco.

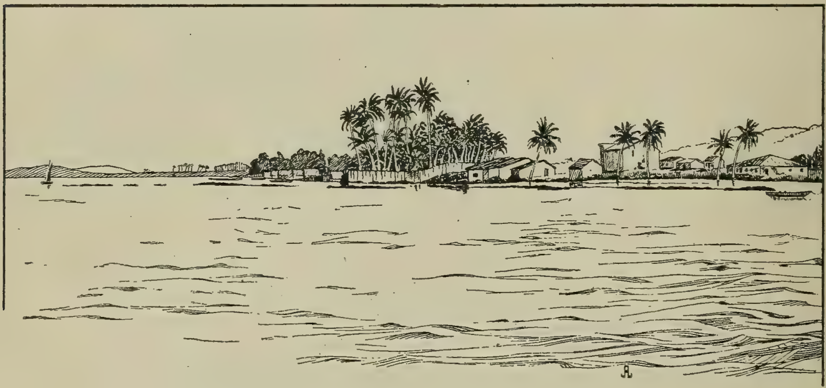

FIGURE 2.—*Ponta de Pedras, Permbuyo, looking Southwest.*

No unconformity has been found between the highly colored upper beds and the gray calcareous Cretaceous beds at the base of the hills. The line of demarkation between the weathered and the unweathered beds, however, is so uneven that it looks as though the weathering had affected both the upper and lower strata in much the same manner, regardless of geologic age.

FOSSILS FROM SANDSTONE EXPOSURES OF THE COAST

Further light is thrown on the geology of Parahyba and Cabo Branco by the exposures on the coast south of the cape. Ponta de Pedras is a village on the coast of Pernambuco, in south latitude 7 degrees 37 minutes, between the mouth of Rio Goyana and the northern end of the island of Itamaracá. On the beach in front of the village yellow fossiliferous calcareous sandstones are exposed from about 2 meters above mean tide to and below low tide, and extending about 200 meters along the beach.

The expedition stopped at this place June 17, 1899, just long enough to examine the rocks and gather a few fossils. These fossils were examined by Mr Ralph Arnold, who kindly made the following determinations and correlations :

Fossils from Ponta de Pedras, Coast of Pernambuco[*]

		Also found at—
1.	*Cypræacteon pennæ* White	Rio Piabas.
2.	*Volutilithes radula* (White, not Sowerby)	Olinda. Maria Farinha.
3.	*Volutilithes alticostatus*, White *? V. radula*, White	Maria Farinha.
4.	*Acmæa* sp. nov.	
5.	*Natica neverita* sp. undet	Montserrate, Bahia.
6.	(*Neritina prolabiata*, White.)	
7.	*Turritella elicita* (White, not Stolitzka)	Maria Farinha.
8.	*Vicarya ? daphne* White	Maria Farinha.
9.	*Capulus* sp. nov.	
10.	*Hyponyx* sp. nov.	
11.	*? Melania terebriformis* Morris ?	Itamaracá. Montserrate, Bahia.
12.	*Crepidula* sp. nov.	
13.	*Lucina tenella* Rathbun	Rio Piabas. Maria Farinha.
14.	*Nucula mariæ* Rathbun	Maria Farinha.
15.	*Leda* (*Nuculana*) *swiftiana*, Rathbun	Maria Farinha.
16.	*Corbula ? chordata* White	Maria Farinha. Sergipe. Rio Piabas.
17.	*Corbula* sp. nov.	
18.	*Dosinia brasiliensis* White	Sergipe. Rio Piabas.
19.	*Glycimeris* (*Axinea*) *bineminis* White	Rio Piabas.
20.	*Cardium* (*Criocardium*) *soaresanum* Rathbun	Maria Farinha. Itamaracá.

Of the twenty species here listed, five are new, five are reported from Rio Piabas, state of Pará, nine are found at Maria Farinha, two at Montserrate, Bahia, two in the state of Sergipe, and one at Olinda, Pernambuco. Two were also found at a new locality discovered by the writer at the northeast end of the island of Itamaracá. The specimen from Itamaracá was found in a bed of brown sandstone. The Itamaracá locality is only 11 kilometers south, and Maria Farinha is only 27 kilometers south of Ponta de Pedras.

The resemblance of the fauna found in the Ponta de Pedras rocks to that of the Maria Farinha beds is at once apparent, while the proximity of the localities to each other bears out the theory that the same beds are repeated at these two or three localities. I have elsewhere pointed out that the Maria Farinha beds are Tertiary and not Cretaceous, as was supposed by Hartt, Rathbun, and White.* Mr Arnold bears me out in this conclusion, and he is positive that the beds at Ponta de Pedras are to be correlated with those of Maria Farinha, which Professor Gilbert D. Harris regards as of Midway Eocene age beyond any question.

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[*] Collected by J. C. Branner, June 17, 1899.

About halfway between Ponta de Pedras and Parahyba similar rocks are exposed on both sides of the mouth of a river that enters the sea just north of Tambaba point. The rocks were examined on the beach about 2 kilometers south of the village of Praia de Jacumã, which is in south latitude 7 degrees 17 minutes. Here a reef of the yellow fossiliferous Tertiary calcareous sandstones like that of Ponta de Pedras extend out about 300 meters from the beach and rises a meter or more above mean tidelevel. The surface of this rock is black, and its yellow color only appears on a freshly broken face.

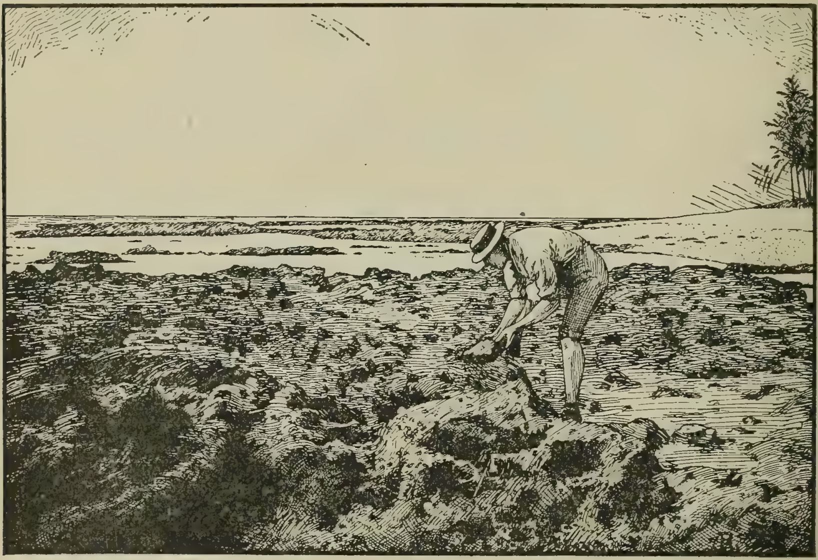

FIGURE 3.—*Reef of Tertiary Sandstone, South of Jacuma.*

This Jacumã locality is just 22 kilometers on a line from the city of Parahyba, and is the nearest to Parahyba of any Tertiary locality that has been identified as such by its fossils.

The exposures between Jacumã and Cabo Branco were not examined.

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* J. C. Branner: The oil-bearing shales of the coast of Brazil. Trans. Amer. Inst. Mining Engineers, 1900, pp. 17, 18 of the separate. The Tertiary age of the Maria Farinha beds was suspected at the time of the publication of Dr White's contributions. See Cretaceous and Tertiary, etcetera, by J. C. Branner, Trans. Amer. Phil. Soc., 1889, vol. xvi, p. 405.

At Cabo Branco a low reef about half a kilometer in length, of hard rough black rocks, barely uncovered at half tide, stands squarely out from the beach. Where examined near the shore these rocks are coarse sandstones, cemented with iron and barren of fossils. The rocks exposed in the cliff at Cabo Branco are chiefly sandstones. The lowest ones are the same as the dark red sandstones exposed in the reef offshore; next above this the rock is purple, red, and gray mottled clay. This clay ends a little more than 1 meter above high-tide level. Overlying the clay is a 5-meter bed of orange colored sands, false-bedded, with lumps and streaks of white kaolin splotching its exposed surface. This bed merges above into red and gray mottled sands and buff sands and loam at the top of the exposed face of the bluff. No fossils were found in any of these beds.

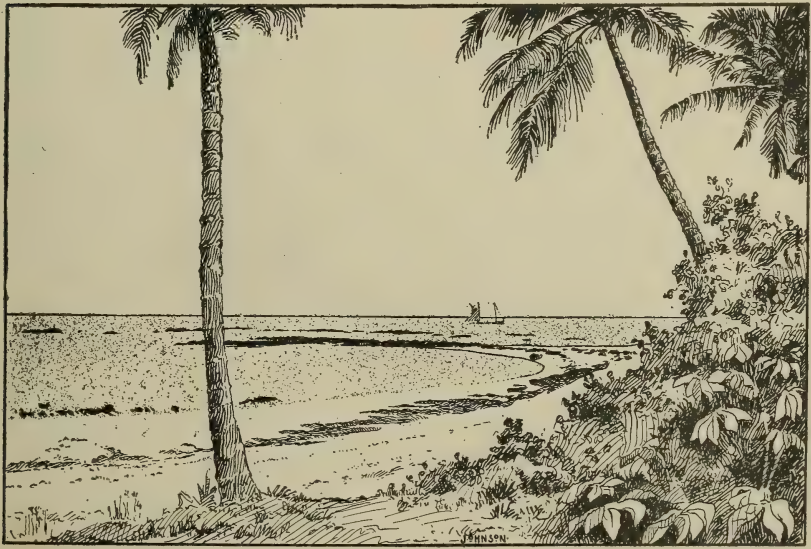

FIGURE 4.—*General View of Tertiary Sandstone Reef.*

The top of the hill at Cabo Branco is about 20 meters above high tide. This point of land is the oceanward or eastern end of the plateau on which the city of Parahyba is built. The Cabo Branco hills continue as an unbroken bluff from 30 to 50 meters high in a northwesterly direction to that city, while the peninsula ending at Cabedello at the mouth of the Rio Parahyba do Norte is a flat sandy plain lying north of this bluff. As the beds exposed at Cabo Branco contain no fossils, it is impossible to say whether they are Tertiary or Cretaceous, but the stratigraphic position of the beds makes it seem possible that they belong to the Tertiary.

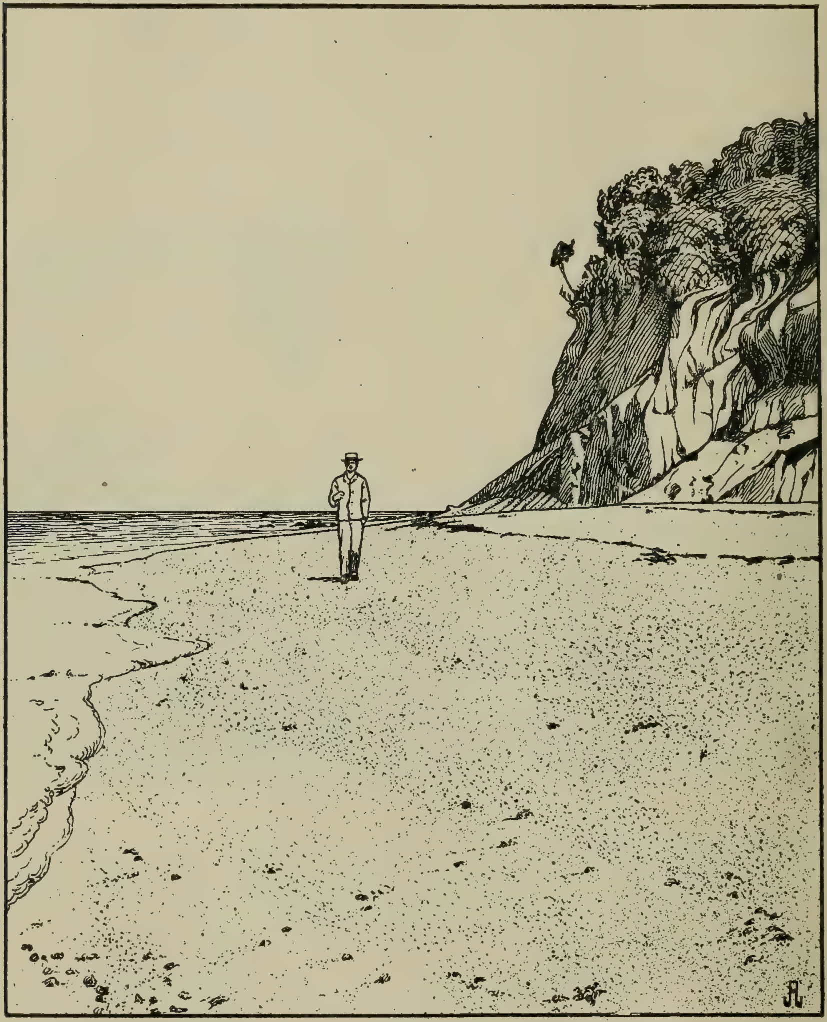

FIGURE 5.—*Cabo Branco.*

GENERAL GEOLOGIC RELATIONSHIPS

We have, then, in the state of Parahyba about the same geology that we have at Olinda, Maria Farinha, Iguarassú, and Itamaracá, namely, sedimentary beds of both Cretaceous and Tertiary ages dipping gently seaward.

It is to be expected, then, that the Conde d'Eu railway, running as it does along the valley of the Parahyba, is near the contact between the Tertiary and Cretaceous beds, and in the absence of paleontologic evidence there is no telling whether the sediments forming the hills south of the railway between Parahyba and Espirito Santo belong to the one or the other of these geologic divisions. The beds forming the hilltops nearer the coast are probably all Tertiary, but at the extreme western edge of the sediments one has usually nothing but the lithologic characters of the rock to guide him, and these, as a rule, are not to be depended on.

RESULTS OF EXAMINATION OF EXPOSURES ALONG THE CONDE D'EU RAILWAY

The following notes were made in two trips along the railway west of Parahyba and four trips between Cabedello and Parahyba:

Stations of the Estrada de Ferro Conde d'Eu

Kilometers.	Station.	Elevation above tide (aneroid).
		Meters.
0	Molhe (pier)	....
2	Cabedello	3.0
11	Jacaré	....
20	Parahyba	1.0
....	Fabrica de Tecidos	....
32	Santa Rita	9.1
....	Usina S. João	....
40	Reis	9.1
46	Espirito Santo	....
51	Entroncamento	11.5
53	Cobé	....
66	Sapé	94.5
76	Araça	110.0
86	Pau Ferro	....
96	Mulungú	62.5
113	Caxoeira	65.5
118	Independencia (old Guarabíra)	70.0

The Conde d'Eu railway now runs from Cabedello, 20 kilometers north of the city of Parahyba, to Independencia, formerly called Guarabíra, in the interior of the state, a total distance of 118 kilometers. From the accompanying sketch map it will be seen that it follows nearly due west up the Parahyba to Entroncamento 31 kilometers, where the main line turns northward and crosses the watershed into the drainage basin of the Rio Mamanguape and ascends the northern side of that stream's basin.

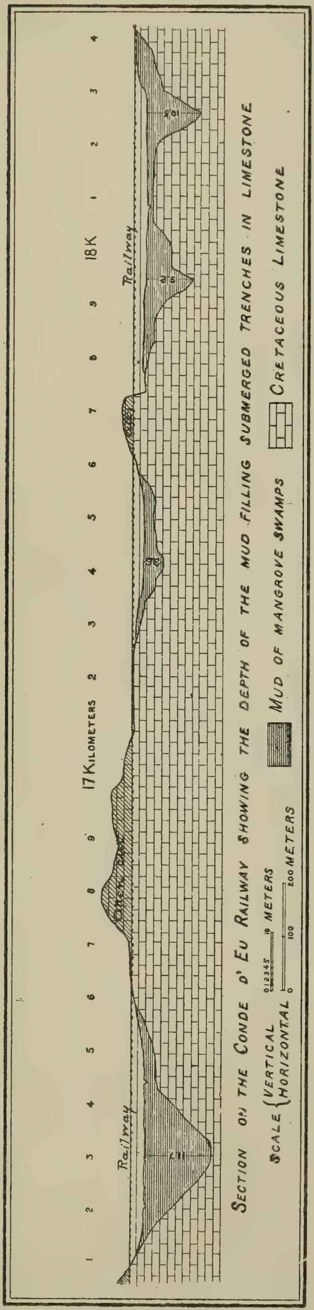
SECTION ON THE CONDE D' EU RAILWAY SHOWING THE DEPTH OF THE MUD FILLING SUBMERGED TRENCHES IN LIMESTONE
SCALE VERTICAL 0 1 2 3 4 5 10 METERS
HORIZONTAL 0 100 200 METERS
MUD OF MANGROVE SWAMPS
CRETACEOUS LIMESTONE
17 KILOMETERS
18K
Railway
Railway

FIGURE 6.—*Geological Section on the Conde d' Eu Railway.*

Between Cabedello and Parahyba the line crosses an almost perfectly flat sandy plain that rises only 2 or 3 meters above tidelevel. In a well put down at the railway shops at Cabedello, marine shells are reported to have been found at a depth of 7 meters below the surface of the ground. The writer did not see these shells. On both sides of the peninsula there are small local exposures of slightly consolidated calcareous sands, in places made up largely of triturated calcareous seaweeds. These sands are apparently of late geologic origin.

A short distance north of the city of Parahyba the railway passes across alternate mangrove swamps and arms of high firm ground which extend from the hills of Parahyba toward the estuary. The high ground of these arms usually rises only a few decimeters above tide-level in the mangrove swamps. One of these ridges, however, has an elevation of several meters where crossed by the road, and there is a cut more than 2 meters deep for the railway bed. This cut is in the gray, marly looking limestone that resembles some of the Cretaceous limestone of the Sergipe basin. Unfortunately there was no opportunity to examine these beds for fossils.

Especial attention is directed toward this part of the railway line on account of the light thrown on the geographic history of the coast by the depth of the muck in the mangrove swamps.* This portion of the railway, the prolongation from Parahyba to Cabedello, was built in

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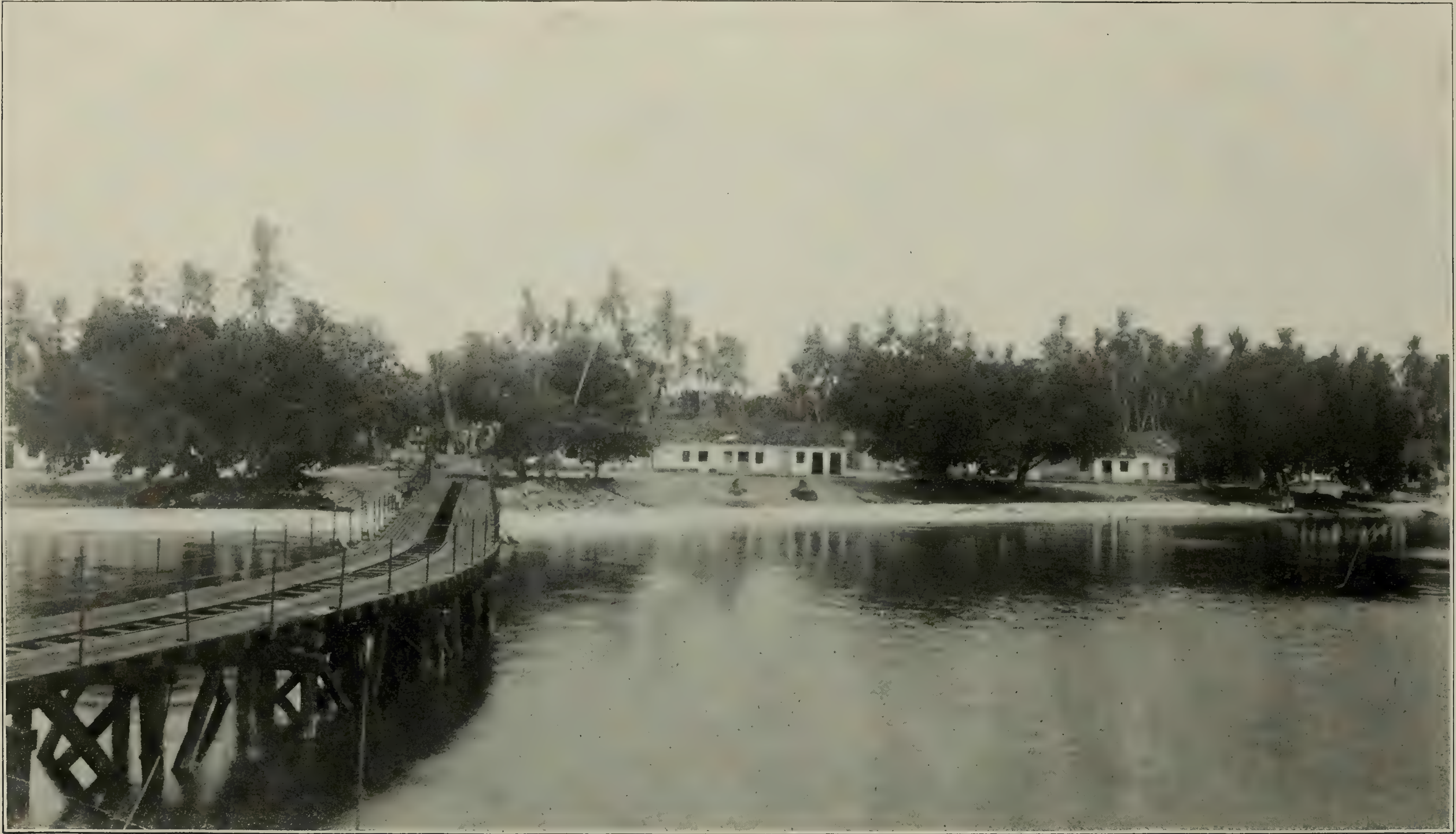
*I am indebted to Mr Samuel H. Agnew, now superintendent of the Natal a Nova Cruz railway, for the copy of the profile and record of soundings on this part of the railway.



SAND PLAIN AT CABEDELLO, PARAHYBA DO NORTE

1887–'88. Where the line crosses the ends of the mangrove swamps northeast of Parahyba, great difficulty was experienced in building the road on the soft mud on account of its yielding and slipping from beneath the load of earth that had to be heaped on it to form the roadbed. As there are cuts in solid rock on both sides of one of the swamps, it was supposed that the swamps had rock bottoms, and soundings were therefore made in the swamp to find the depth to the rock. These soundings were successfully made with steel rods, and the mud was so soft that two rods were lost by being dropped endwise in the mud; they are said to have sunk almost as promptly as if they had fallen in water.

The accompanying profile shows the form of the rock bottoms of these swamps. The greatest depth of the mud found on the line was 11.70 meters. It seems evident that the swamps here fill gullies formerly cut in the gray Cretaceous limestone. Inasmuch as gullies can be cut at such a place only when the surface is above waterlevel, it is inferred that the land hereabouts formerly stood enough higher to allow water to flow down through these channels. The present conditions have been brought about by a depression of the old land surface that has carried the ancient valleys beneath the sea, and the upper ends of these valleys have been filled with silts and then overgrown with vegetation. The depth of these channels shows that the amount of the land depression was 12 meters at least; but inasmuch as the soundings were made close to the Parahyba hills, it seems highly probable that farther west the Parahyba estuary now covers the main channels and that they are much deeper than 12 meters.

The railway station at Parahyba is at the foot of the Cretaceous hills on one side, while to the west and north stretch the mangrove swamps of the Parahyba estuary. Three kilometers from the city of Parahyba the track of the railway skirts a steep-sided hill on the left, with a mangrove swamp on the right. The valleys along this portion of the road are flat-bottomed. At Usina São João the flat valley floor of the Rio Parahyba is about 4 kilometers wide. At kilometer 22 (from Parahyba) there is a great flat freshwater marsh whose sides end as sharply against the hills as if made by a body of water. The surface of this marsh is about 5 meters above tidelevel (aneroid). An attempt was made to build the railway across one of these marshes, but the roadbed sank under the load made by the fill and the line had to be changed. This fact is of interest in connection with the soundings made in the mangrove swamps between Parahyba and Cabedello already mentioned. It seems probable that the valley-cutting done during the period of elevation extended this far, and that we have here another silted-up narrow valley.

The railway cuts east of Santa Rita are in Cretaceous (or Tertiary) sediments, some of them false-bedded. At Santa Rita the railway station is 6 meters above the flat valley floor and 9 above tide-level. From Santa Rita to Reis the railway cuts expose only soil and sedimentary beds.

Between Reis and Espirito Santo the line of the railway crosses a series of short finger-like hills which project toward and into the marshes of the Parahyba valley from the high country south of it. Fresh-water marshes extend from near the station of Espirito Santo eastward for about 1 kilometer. This station is on a flat plain 4 or 5 meters above the level of the water in the fresh-water marshes. The railway here skirts the foot of the sedimentary plain which extends southward from the Parahyba river.

The Cretaceous (or Tertiary) beds end on the railway line between Espirito Santo and Entroncamento, and the first crystalline rocks appear shortly before the latter station is reached. At Entroncamento, 31 kilometers from the city of Parahyba, freshwater marshes of the Parahiba are about 7 meters above tidelevel. The immediate valley of the Parahyba is less than 1 kilometer wide where crossed by the railway, and is flat, ending against rounded and gently sloping hills.

Following up the main line north of Entroncamento there is a railway cut exposing schists with quartz veins about 200 meters south of Cobé station. One kilometer north of Cobé is another cut in quartz-veined schists. One and a half kilometers beyond and north of Cobé, and at an elevation of 58 meters above tide, waterworn pebbles, some of them as large as one's fist, are exposed along the railway at a depth of from 1 to 2 meters below the surface of the red soil and following the surface contour of the hills. In some places, however, these pebbles are wanting.

The station of Sapé is on the flat plateau-like divide between the Parahiba and Mamanguape rivers; its elevation is 94.5 meters above tide. Looking southward from Sapé one may see that the floor of the Parahyba valley is remarkably flat and even, while the skyline beyond is much broken. For 20 kilometers the railway follows the flat plateau; this same taboleiro extends eastward nearly to the sea, forming the tablelands between the Parahyba and the Rio Mamanguape. There are but few exposures along the railway where it crosses this flat plateau, so that the geology is not well shown. So far as it is visible, it seems to be a plain of crystalline rocks cut off rather evenly and having a thin coating of sedimentary beds spread over it. At the margins of the plain the cuts expose crystalline rocks overlain with waterworn boulders. About 2 kilometers west of Araça the railway descends from the plateau of particolored sediments into the Mamanguape valley. At an elevation of 73 meters and up to 82 meters above tide, there are waterworn boulders, some of them half a meter in diameter, overlying crystalline schists. Farther down the side of the valley the schists are all more or less decomposed and are overlain with a line of waterworn pebbles, and above these is the soil of a deep red color.

Two or 3 kilometers east of Pau Ferro are good exposures of the schists with overlying waterworn boulders. The gravel is from 1 to 2 meters thick and especially heavy about 100 meters east of the station of Pau Ferro. The gravel bed is generally covered by from 1 to 2 meters of soil.

At Pau Ferro station (66 kilometers from Parahyba) a well has been dug east of the railway track in the lower part of the valley, and from this were taken many waterworn boulders. The pebbles in the vicinity are subangular rather than round, though clearly waterworn. Northwest of Pau Ferro are several cuts along the railway in which schist is exposed with waterworn materials overlying it. One of these cuts is about 5 meters deep; the gravel beds overlying the schist are a meter or more in thickness, but they thin down and almost disappear in places. This sheet of waterworn gravel passes completely over the lower watersheds. The soil over the schist is in places not more than half a meter thick. There are white bands of pegmatite in some of the exposures of crystalline rocks.

Mulungú station (elevation, 62.5 meters) stands on a black clay or soil that forms the flat floor of a narrow valley draining into the Rio Mamanguape. This black muck-like soil looks like the bottom of an old lake or swamp. The soil is the so-called "massapé." In the dry season it opens in big cracks.

In the Mamanguape valley there are several lakes apparently in process of filing up with organic matter.

On the divide between the Mamanguape and Caxoeira station, at an elevation 94 meters, some of the schists are very micaceous, and the pebble bed is heavy, coarse, and widespread. South of Caxoeira station (93 kilometers from Parahyba) schists decayed in places so closely resemble the particolored sediments on the coast that at a distance of 10 meters they could not be distinguished from each other. On closer inspection the bedding planes (or schistosity) of the shist may be traced through the colored earth. The earth produced by the decomposition of the shist here is sometimes highly colored and sometimes gray.

Independencia, formerly known as Guarabíra, is the terminal station of the railway. It is 98 kilometers from the city of Parahyba, and has an elevation of 70 meters above tide, and is about 45 kilometers from the seacoast. The rocks exposed in place about the town are all schists, but among the heaps of stones brought together for building purposes are occasional small blocks of a diabase-like rock, evidently boulders of decomposition. The schists are cut by many quartz veins and the slopes of the low hills are strewn with a thin covering of waterworn boulders. Some of these boulders are nearly half a meter in diameter.

In a cut made in the town for the prolongation of the railway the schists are well exposed; they are not much crumpled but they split readily. From the hills about Independencia the topography has the appearance of a peneplain into which the streams have cut their valleys and above which the higher peaks rise.

There are a few places along the line of this railway where there are large exfoliated boulders or bare rounded rocks in place.

Alagôa Grande was not visited, but Mr H. G. Sumner tells me that the hills in the vicinity of that place are all of granite or other crystalline rocks. The accompanying plates from photographs by Mr Sumner show the character of the topography of that region.

The writer has not examined the geology farther west in the state of Parahyba, but a few notes of value are available from the observations of others.

In 1854 a French physician, Jacques Brunet, was authorized by the president of the province of Parahyba to explore its interior. He sent to Mr Burlamaque, of the Museo Nacional, at Rio de Janeiro, two fossil shells found in the Serra de Teixeira.*

In a somewhat later paper Dr Burlamaque says † that Brunet sent specimens of limestone from Rio do Peixe and São João in the extreme western part of Parahiba; he also sent salt-bearing clays from Area. These localities are not far from the Cretaceous beds of the interior of Ceará.

Williamson's trip to the interior, made in 1866, extended to Piancó, about 265 kilometers west of Independencia. The rocks over most of this distance are reported by him to be granites, gneisses, and schists, but on the western side of the Serra da Borborema, "at Teixeira, where granitoid rocks abound, large quantities of brecciated conglomerates, sands, and marls are found flanking the mountains and covering the valleys." ‡ It seems probable that these sedimentary beds are the ones from which Brunet obtained the fossil shells, and that they are the re-

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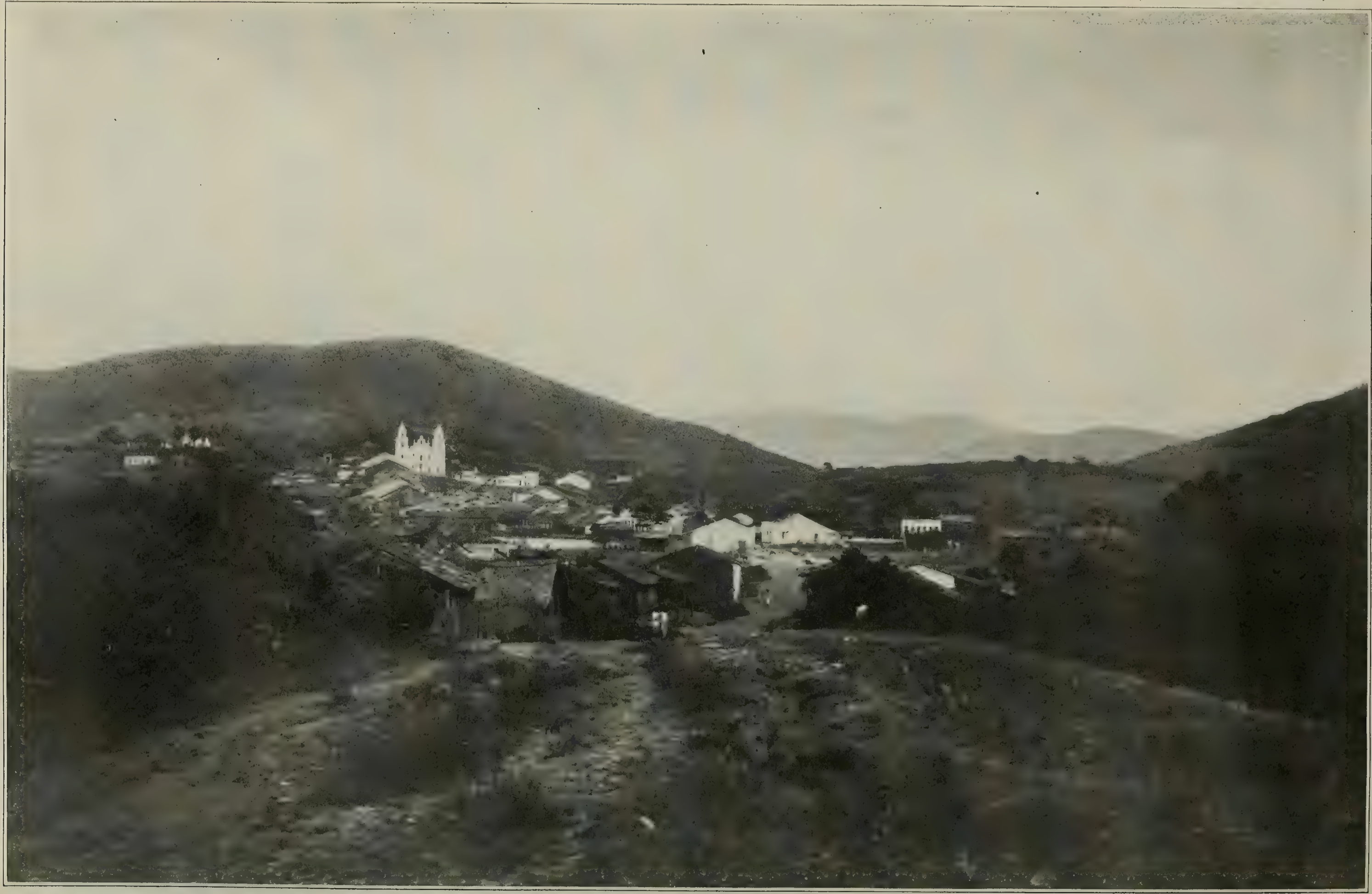
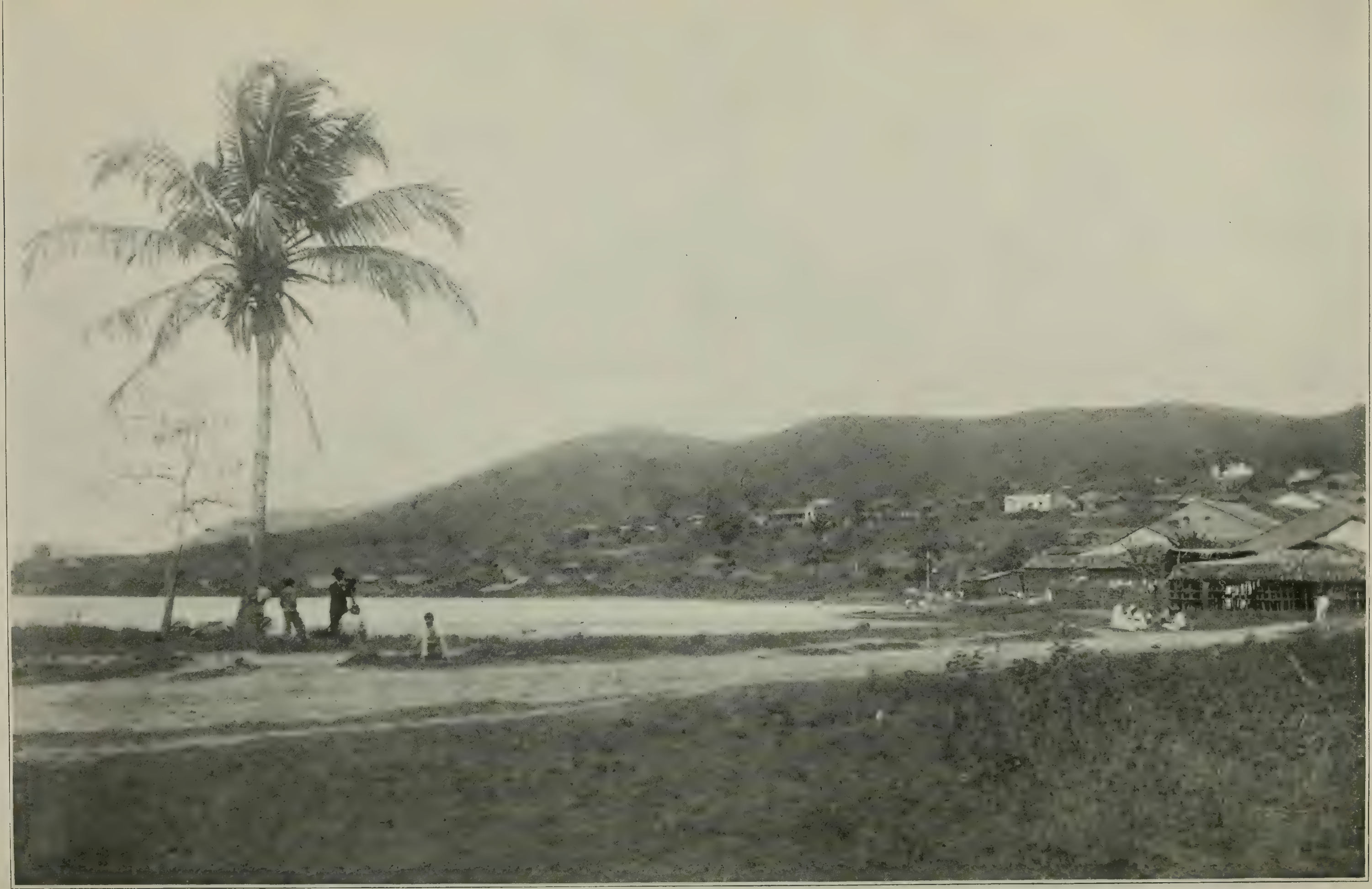
* Noticia acera dos animaes de raças extinctas descobertos em varios pontos do Brazil. Pelo Dr F. L. C. Burlamaque. Bibliotheca Guanabarense. Trabalhos da Sociedade Vellosiana, 1855, pp. 19, 20.

† Noticia acerca de alguns mineraes e rochas de varias provincias do Brazil, recebidos no Museo Nacional durante o anno de 1855. Por Dr F. L. C. Burlamaque. Revista Brazileira, Rio de Janeiro (1858), vol. ii, pp. 73–104.

‡ Williamson: Geology of Parahiba and Pernambuco gold regions, Trans. Manchester Geol. Soc., 1867, vol. vi, p. 115.



GRANITE HILLS AT ALAGOA GRANDE, PARAHYBA DO NORTE



LAKE IN THE GRANITE REGION OF ALAGOA GRANDE, PARAHYBA DO NORTE sidual eastern and southern edges of the great Cretaceous area of the interior of Ceará and Piauhý, or perhaps they might more properly be called the fragmentary outliers between the Cretaceous area of the interior and the Cretaceous along the coast, and known to occur at Parahyba and in the states of Alagôas and Sergipe.

A short paper published by a Brazilian engineer in 1886 contains a few points of interest in connection with the geology of the interior of the state of Parahyba.* This writer mentions the existence of caves in the interior of Parahyba, a fact that leads to the inference that there are limestones in the region referred to. He also mentions † the finding of the bones of large extinct animals—probably mastodons. He speaks of the existence of iron, coal, lead, marl, limestone, and flint in the interior, but he does not specify the localities.

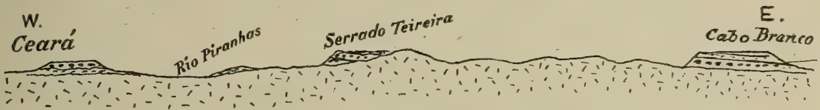


FIGURE 7.—*Idealized Section from Cabo Branco to Frontier of Ceará.*

CONCLUSIONS REGARDING THE GEOLOGY OF PARAHYBA DO NORTE

1. The leaden gray rocks exposed at the base of the hills at the city of Parahyba are fairly good limestones and are of Cretaceous age.
2. The yellow Calcareous sandstones exposed on the coast south of Jacumã and at Ponta de Pedras are equivalent to the Maria Farinha beds of Pernambuco and are of Tertiary age.
3. The particolored beds forming the tops of the hills at Parahyba and those in the bluffs at Cabo Branco are probably the weathered portions of the Tertiary, but no unconformity is known between them and the Cretaceous beds.
4. In the absence of fossils it is not possible to distinguish between the Cretaceous and Tertiary, and hence the sedimentary beds exposed along the Conde d'Eu railway cannot at present be assigned to either group with certainty.
5. The sedimentary beds form the highlands along the line of the railway from Parahyba to a point between the stations of Espirito Santo and Entroncamento—a distance by rail of nearly 30 kilometers.
6. The sedimentary beds (Tertiary and Cretaceous together) have a width along this coast of only 30 or 40 kilometers.
7. The sedimentary beds are not thick, and the underlying crystalline

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* Relatorio que o engenheiro de minas Francisco Soares da Silva Retumba dirigio ao Exm. Sr Dr Antonio Herculano de Souza Bandeira, Presidente da Parahyba. Pernambuco, 1886, 46 pp.

† Loc. cit., pp. 16–17.

rocks are reported to be exposed at Batalha on the Rio Parahyba, within the area covered by the sedimentary beds.

8. It seems probable that the sediments all dip gently eastward, so that the Cretaceous beds are occasionally exposed inland, while they are not visible on the coast.

9. The watershed between the Parahyba valley and that of the Rio Mamanguape is of crystalline rocks, thinly covered with sedimentary beds. The waterworn material of the plateau is coarser on the lower slopes than on the top of the plain.

10. The Cretaceous beds rest on schists and other crystalline rocks.

11. The schists are nearly everywhere cut with quartz veins; these veins are generally less than half a meter in thickness.

12. The schists are not much wrinkled, but they stand at high angles—from 50 to 75 degrees.

13. The crystalline rocks are all more or less decomposed, so that many of the railway cuts through them have been made with picks. In some places they have been blasted. The cuts in the hard rocks, however, are nowhere more than 4 or 5 meters deep.

14. In the vicinity of Independencia the crystalline rocks contain dikes of dark diabase-like eruptives.

15. The crystalline rocks of the interior have been called Laurentian by Williamson, but while they lithologically resemble some of the so-called Laurentian beds of Canada, no trustworthy evidence has been found of their age or ages.

16. The general topography shows that there has been a late depression of this coast region; that the water filled the valleys near the coast, and that these valleys afterward silted up and are now partly occupied by mangrove swamps. This history is borne out also by the soundings made in the mud of the mangrove swamps near Parahyba.

17. The depression of the coast was more than 12 meters.

18. The remains of extinct Pleistocene vertebrates are reported from the interior of the state.

19. Fossils and limestones are reported from the interior of the state, but no facts are available to indicate whether these limestones and fossiliferous beds belong to the Cretaceous or with the Paleozoic series. The lithologic character of some of the limestones and the geographic position of the rocks suggest that they are Cretaceous.

Geology along the Pernambuco Coast South of Recife

LOCATION AND CHARACTER OF THE EXPOSURES

In July, 1899, I made a trip on foot along the coast south of Pernambuco, and some of the observations on the geology are appropriate here

Following the beach southward from Pernambuco, the Tertiary hills that are exposed north and west of the city only reach the coast again to the south near the village of Paiva. Here they are about one kilometer to the southwest of the beach. The beds are horizontal, and are composed of sands, clays, and gravels, and contain no fossils.

TRACHYTES

Two kilometers northwest of the point known as Pedras Pretas the hills come quite down to the beach, but here the hills are of trachyte, with a thin covering of Tertiary sedimentary beds capping them. Near the cape Pedras Pretas the trachytes are quite bare, but over them are a few waterworn quartz pebbles showing that the Tertiary beds have been stripped away.

On weathering the trachyte turns red, yellow, and purple. It has been quarried at the point of land for making street paving blocks for the city of Pernambuco, but the quarries are now no longer worked. Specimens of these trachytes were collected and submitted to Mr H. W. Turner, who kindly furnishes the following descriptions:

> "These rocks are typical trachytes. Macroscopically they are fine grained purplish rocks with rather abundant phenocrysts of feldspar, some of which attain a length of 6 centimeters.
>
> "Microscopically the trachyte is composed of idiomorphic feldspars in a fine grained groundmass of feldspar laths, with indistinct boundaries, which show a tendency to arrange themselves in parallel lines, which curve about the ends of the feldspar phenocrysts, thus exhibiting a typical trachyte texture. Some of the phenocrysts, as well as the larger part of the microlites of the groundmass, extinguish sensibly parallel to their direction of elongation, and have an index of refraction less than that of the balsam. They are thus orthoclase. A few of the phenocrysts are microperthite, showing minute lamellæ, presumably of albite and orthoclase intergrown. These lamellæ extinguish at different angles. A few feldspar laths of the groundmass show albite twinning and extinguish at slight angles. These are probably oligoclase. There are some elongated grains of quartz without crystallographic boundaries present, and these appear to have formed after the feldspars, but, nevertheless, to be original. The microlites show no tendency to arrange themselves around these quartz grains, and in some cases the ends of the feldspars are enclosed in the quartz. A few flattened, nearly rectangular prisms with high relief and brilliant interference colors extinguishing parallel to the prism are probably zircon. There are also rather numerous opaque grains of iron oxide, probably magnetite. The section is obscured by a dust of particles, some of them nearly opaque, but where thin are translucent with red-brown color. These are perhaps limonite formed from the alteration of magnetite, for the magnetite grains show a thin rim of similar material. These reddish grains give the purple color to the rock. A little carbonate is also noted."

On the Pedras Pretas point are several blocks of the trachyte, beautifully pitted by sea urchins. These blocks are now so far above mean tidelevel that they can not be occupied by sea-urchins. It is evident that there has been a recent elevation of this part of the coast, amounting to about 2 meters. There are many other large masses in place similarly pitted.

I recall no other occurrence of trachyte in Brazil. D'Orbigny says that trachytes accompany the porphyries of the western side of the Cordilheiras, but he adds: "No one has noted them in Brazil or in the Guyanas, and I have only seen them in the Cordilheiras or on their western slopes." *

GRANITE AT GAIBÚ

South of Pedras Pretas the next rocks of interest in this connection are exposed at the village of Gaibú, just north of Cabo Santo Agostinho. The rocks at this place are coarse grained gray granites. They are exposed at the foot of the hill, southwest of the village, where an old fort stands on them.

Southwest of the village of Gaibú is a high hill of Tertiary sedimentary beds overlying the granite. Following the foot path across Cabo Santo Agostinho, from Gaibú to the village of Suápe, the granite continues halfway up the hill, but the top of the ridge is of Tertiary sediments. About the light-house on the cape, and especially on the north side of it, are many enormous exfoliated boulders of granite.

GRANITES AND DIORITE OF CABO SANTO AGOSTINHO

The granite runs all the way round Cabo Santo Agostinho from Gaibú to Suápe in one form or another, and only on the top of the ridge are there patches of Tertiary sediments.† On the south side of the cape are several quarries in the granite-porphyries, all of them now idle.

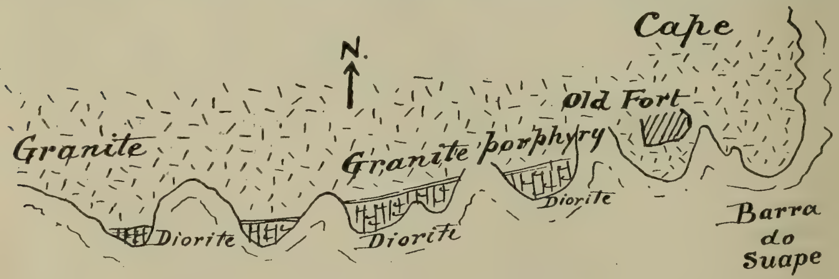

FIGURE 8.—*Geology on South Side of Cabo Santo Agostinho.*

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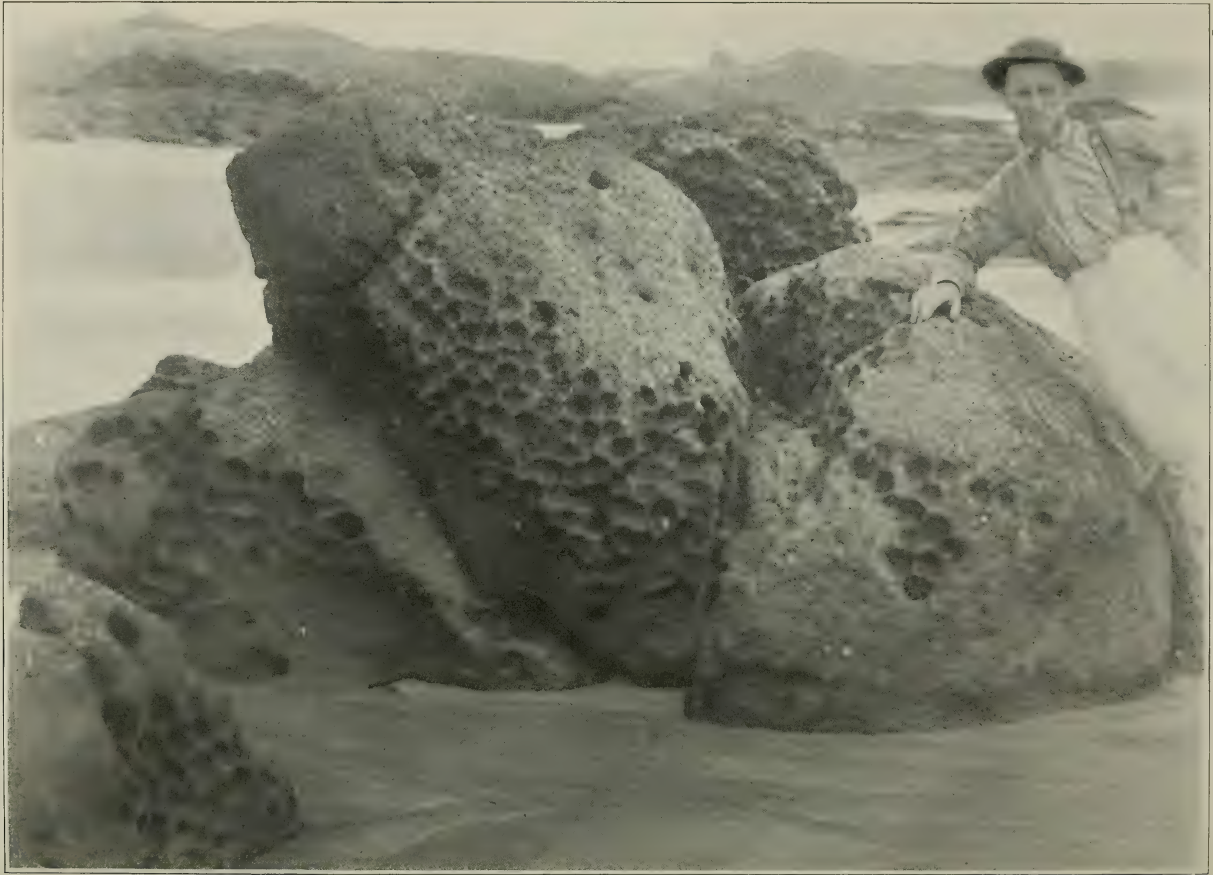
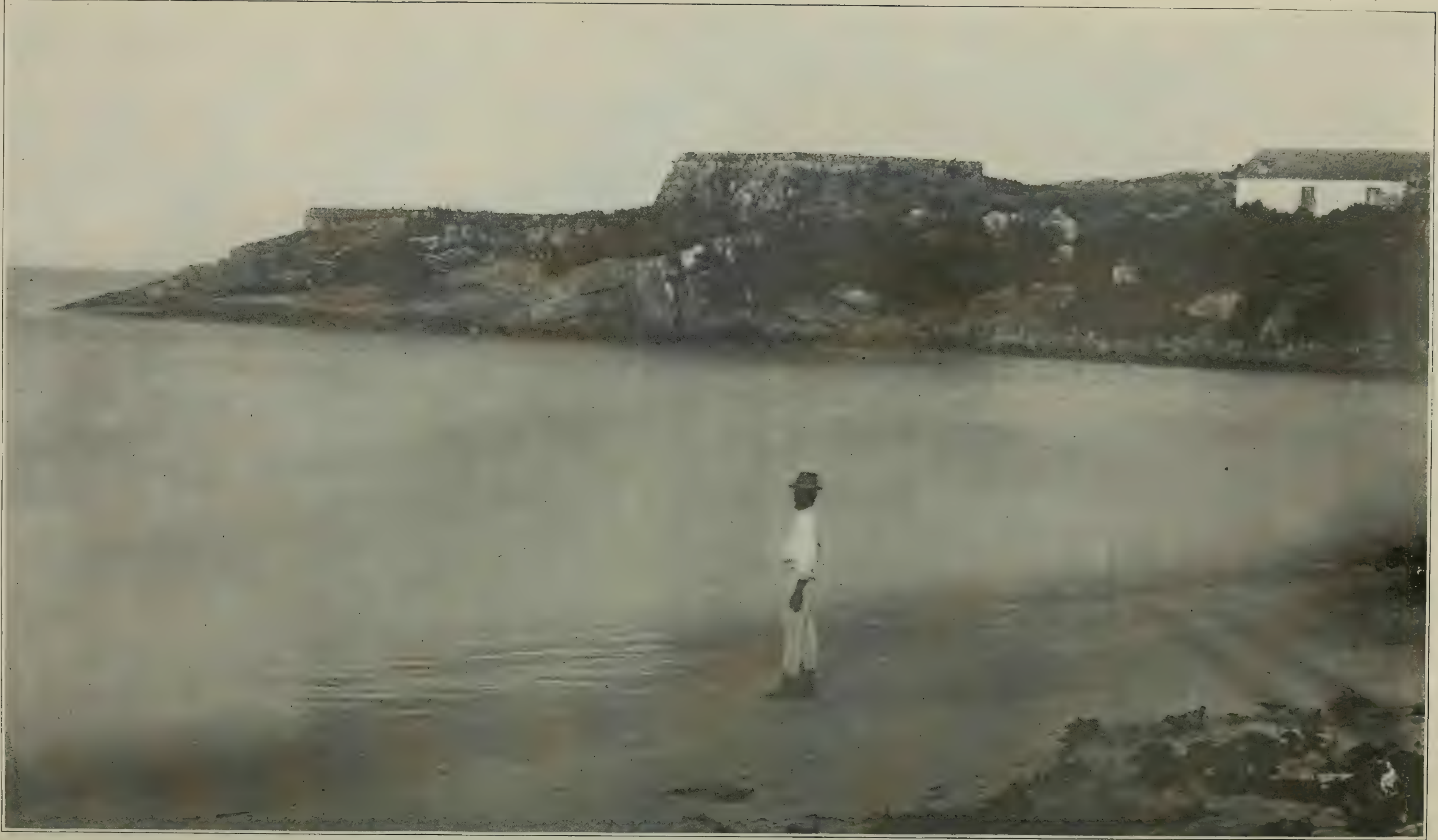
* Voyage dans l'Amérique Méridionale, t. III. 3e Partie, Géologie, pp. 215–216. Paris, 1842.

† The rocks here spoken of as Tertiary have thus far afforded no evidence whatever of their age. Their stratigraphic position and their lithologic characters would both admit of their being Cretaceous quite as readily.



SEA URCHIN BURROWS IN TRACHYTE AT PEDRAS PRETAS, PERNAMBUCO



GRANITE POINT AT GAIBÚ CABO SANTO AGOSTINHO, PERNAMBUCO

On the south side of the cape the granites are of two kinds—coarse granites and granite-porphyries. Through the porphyries is an altered dike of diorite, running about parallel with the hill, between the old fort at the bar and halfway to the village of Suápe. The rock on both sides of the diorite is granite-porphyry, and small dikes of the porphyry penetrate the larger dike of dark green diorite. The old fort on the point of the cape near the Barra do Suápe stands on the porphyry, but farther north the rock is a granite. These three rocks from Cabo Santo Agostinho have also been described by Mr Turner as follows:

"The granite from cape Santo Agostinho is a coarse rock composed of orthoclase, microperthite, and quartz, with frequent wedges of a strongly pleochroic green-blue amphibole between the other constituents.

"This amphibole is in the form of longitudinally striated prisms, which are black as seen with a hand lens. The pleochroism is strongest (dense blue) where the cleavage lines are parallel to the horizontal cross-hair. The extinction was not determined on account of the dense color.

"A fragment of this amphibole was treated with hydrofluosilicic acid, there resulting little hexagonal sodium fluosilicates, a few octahedral anistropic crystals of undetermined nature, and some thorn-like anistropic forms radiating from a center much resembling calcium fluosilicates. The presence of sodium, together with the character of the pleochroism, suggests that this amphibole is allied to riebeckite. Calcium is present in some analyses of riebeckite.*

"The granite forming a dike in the diorite is, macroscopically, a light colored coarse rock, composed of light-buff feldspar, quartz, and dark-greenish material.

"Microscopically, it is composed of orthoclase, microperthite, and quartz, with a little reddish-brown strongly pleochroic biotite and a strongly pleochroic green-blue amphibole, with marked cleavage resembling riebeckite and similar to the amphibole described under the preceding specimen.

"The granite porphyries from cape Santo Agostinho are macroscopically light-gray fine grained granolites, showing porphyritic quartzes up to 1½ millimeters in diameter and porphyritic pinkish feldspars up to 2 millimeters in diameter.

"Microscopically, the rock contains numerous phenocrysts of turbid feldspars, often in simple twins, and squarish and hexagonal, sharply idiomorphic, quartz phenocrysts in a microgranular groundmass of quartz and feldspar. The feldspar, both in the phenocrysts and in the groundmass, is largely microperthite, but orthoclase is also present. There are occasional small opaque grains of metallic iron oxide, probably magnetite, and grains and minute prisms with high relief, showing strong cleavage and bright interference colors extinguishing parallel to the prism.

"In one specimen of the granite porphyry there are very abundant minute rectangular pleochroic crystals showing a single cleavage parallel to the sides of the rectangle. The pleochroism is reddish brown when the vertical cross-hair is parallel to the cleavage, and nearly black at right angles to this direction.

"The diorite from cape Santo Agostinho is macroscopically dark and fine grained, microscopically a cataclastic igneous rock, showing crushed feldspars and secondary amphibole in a fine feldspathic groundmass. The rock has undergone strong shearing. The feldspars are in part twinned on the albite law and one or two on the Carlsbad law, and they show an index of refraction greater than that of the balsam. One quartz, apparently original, was noted. The feldspars are undoubtedly plagioclase, probably andesine. One grain of quartz that appeared to be original was noted. There is magnetite present, and abundant minute secondary grains of undetermined nature."

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*Dana: System of Mineralogy.

One of the rocks collected on the south side of Cabo Santo Agostinho, where the relations of the granite, granite porphyry, and diorite to each other is not altogether clear, is described by Mr Turner as a *meta-rhyolite*, "evidently original glass, now devitrified," an occurrence of interest in connection with the rhyolites at Santo Aleixo.

ROCKS OF SANTO ALEIXO

The next rocks of especial interest are those of the little island of Santo Aleixo, 30 kilometers south of Cabo Santo Agostinho.

On the beach opposite and west of the island, and just south of Serambý point, the sands are black instead of the usual straw color. As this is the only place at which such sands were seen on more than 300 kilometers of beach examined, it seems that these must have been derived from the eruptive rocks of the island of Santo Aleixo opposite. Specimens of this sand were collected, and Mr Turner, who kindly examined them for me, says of them:

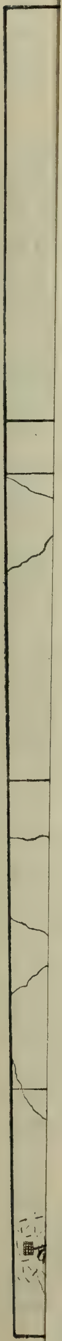
"The most abundant mineral is the black iron oxide, which is not magnetic except with the electromagnet, which was used to separate it from the remainder of the powder. This iron oxide gives a reaction for titanium, and hence is rather certainly ilmenite. Corundum, garnet, and feldspar are also present, and several other minerals, as yet undetermined."

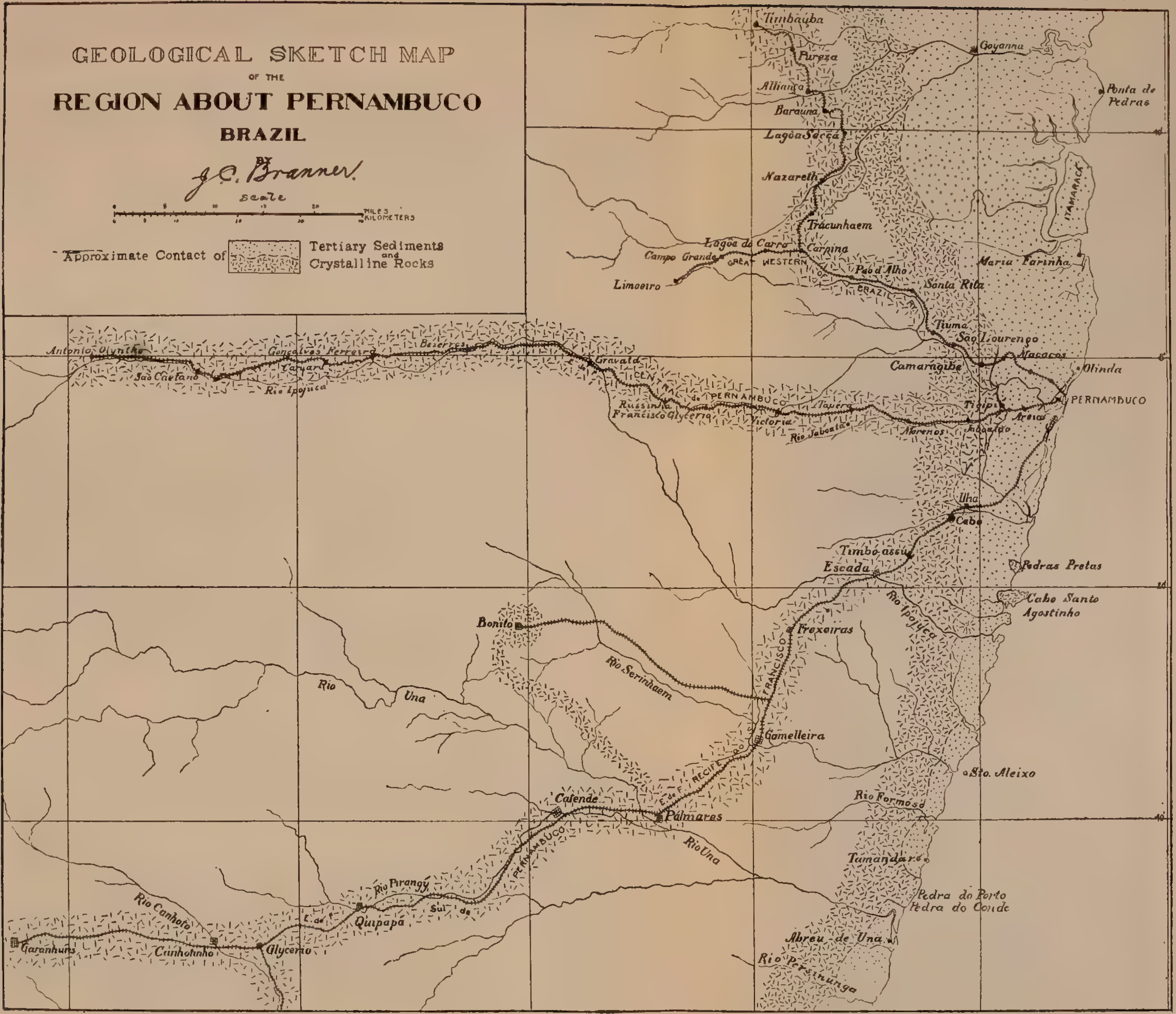
The rocks which form nearly all the little island of Santo Aleixo are rhyolites. Several years ago I submitted to Dr George H. Williams specimens that I had collected on Santo Aleixo. He found them to be rhyolites, and wrote as follows regarding them:

"They are quartz orthoclase aggregates with almost no bisilicate constituents, but their structures are varied. One of the specimens has a granular holocrystalline groundmass of quartz and feldspar, some chlorite, possibly representing original hornblende or mica, and considerable blue tourmaline. The other Santo Aleixo specimen is a fine granophyre. Porphyritic quartz and feldspar lie in a holocrystalline groundmass which is filled with beautiful spherulites, showing the black cross between crossed nicols. . . . There is no nephelene in any of these rocks."

Professor Derby has lately suggested in a private letter, dated July 29, 1901, the theory that the Santo Aleixo rocks "might prove to have

BULL.




GEOLOGICAL SKETCH MAP
OF THE
REGION ABOUT PERNAMBUCO
BRAZIL
BY
J. C. Branner
Scale
MILES
KILOMETERS
Approximate Contact of
Tertiary Sediments
and
Crystalline Rocks
Timbauba
Goyanna
Ponta de Pedras
Pureza
Alliança
Barauna
Lagôa Secca
Nazareth
ITAMARACA
Tracunhaem
Lagoa do Carro
Carpina
Campo Grande
GREAT WESTERN
Pao d'Alho
Maria Farinha
Limoeiro
Santa Rita
BRAZIL
Tiuma
São Lourenço
Macacos
Camaragibe
Olinda
PERNAMBUCO
Antonio Olyntho
Bezerres
Gonçalves Ferreira
Gravatá
São Caetano
Tapyar
Rio Ipojuca
CENTRAL de PERNAMBUCO
Russinha
Francisco Glycerio
Victoria
Tapera
Tigipió
Areias
Rio Jaboatão
Morenos
Jaboatão
Ilha
Cabo
Timbó assú
Escada
Pedras Pretas
Cabo Santo Agostinho
Rio Ipojuca
Bonito
Frexeiras
Rio Serinhaem
S. FRANCISCO
Rio
Una
Gamelleira
Sto. Aleixo
Rio Formoso
RECIFE
Catende
Palmares
Rio Una
PERNAMBUCO
Tamandaré
Rio Pirangy
Pedra do Porto
Pedra do Conde
Rio Canhoto
Sul de
E. de
Quipapá
Abreu de Una
Garanhuns
Canhotinho
Glycerio
Rio Persinunga

GEOLOGICAL MAP OF THE REGION ABOUT PERNAMBUCO

some connection as an acid phase with the Fernando de Noronha eruptive epoch, and that the same magma might give a granite in the neighborhood."

RIO FORMOSO ROCKS

The Tertiary sediments are exposed in all the prominent hills and occasionally on the streams or estuaries at low tide south of Santo Aleixo as far as the mouth of Rio Formoso. At Rio Formoso the granites are exposed on the south side of the river about 3 kilometers from the sea, and from that point up stream as far as the town of Rio Formoso. There is therefore only a narrow belt of the Tertiary at this place.

The hills near the coast are all Tertiary and isolated, but between them are occasional exposures of soft sediments that appear to be of later Tertiary age. Along the shore, between the mouth of Rio Formoso and Praia da Gamella is an interesting exposure of these later Tertiary rocks. The beds are horizontal, and are being rapidly attacked by the waves, marked changes having taken place between January, 1876, when the locality was first examined, and July, 1899. The lowest bed exposed is soft white sandstone, 2 meters thick. On top of this is a bed of soft black sandstone, the two being separated by about 2 centimeters of yellow clay. On top of these two beds is beautiful white quartz sand from 3 to 6 meters thick. The bed in place is 3 meters thick, and in some places it has been blown over and another 3 meters heaped on top. This sand appears to be available for the manufacture of glass, and there is an abundance of it.

These Tertiary beds are exposed from Gamella nearly to the hill on which stands the church of Nossa Senhora de Santa Anna and against which the beds end. The hill of Nossa Senhora de Santa Anna is of Tertiary rocks also, but these beds belong to the older series.

GRANITE OF PEDRA DO PORTO

Northwest of the village of Tamandaré the horizontal colored Tertiary is exposed in the hills at two places. About 6 kilometers south of Tamandaré the hills come down to the coast and the granites are beautifully exposed on the beach at a point known as Pedra do Porto. The following is Mr H. W. Turner's description of the granite found at the Pedra do Porto:

> "The biotite-granite from Pedra do Porto is macroscopically a light gray coarse rock, with large pink feldspar phenocrysts in a coarse groundmass of quartz, feldspar, and biotite.
>
> "Microscopically composed of orthoclase, microperthite, microcline, micropegmatite, oligoclase, quartz, and biotite. As accessories there are present iron-oxide, apatite, titanite, and a xenotime-like mineral."

This granite is beautifully veined with quartz, some of the veins being a meter thick. Gigantic blocks are exfoliating on an impressive scale. From 200 to 300 meters offshore is a small barren rocky island of this same granite. The hills of the granite on the landward side of the beach are 30 or 40 meters high. A little more than a kilometer south of Pedra do Porto is another exposure on the beach of the same kind of granite. This place is called the Pedra do Cônde, and near the beach the granite blocks are beautifully exfoliated. About half a kilometer south of the Pedra do Conde are two round bare islets of granite about 150 meters offshore.

South of this point there are no granites or other crystalline rocks exposed in place on or near the beach as far as Maceio. The rocks seen in place are all Tertiary or recent. The particolored cliffs visible at so many places along the coast are all Tertiary sediments. At a few places, however, there are large granite boulders exposed on the beach and underlying the Tertiary beds. On account of the large size of these boulders, some of them a meter or more in diameter, it is assumed that the granite in place is very near the surface wherever they are found. The following are the places at which the granite boulders occur on the beach: Camáxo, south of Maragogý on the coast of Alagôas; Barreira do Boqueirão just north of Rio Porto Calvo; Morro de Camaragibe about 3 kilometers south of Rio Camaragibe, and Riacho Doce just north of the village of this name.

The following is Mr Turner's description of the granite found at the mouth of Riacho Doce:

> "Microscopically it is a medium grained granite composed of orthoclase, microcline, oligoclase, and quartz. The quartz occurs in aggregates of interlocking grains of smaller size than the feldspars. There is a small amount of a yellow-brown nearly opaque substance filling cracks and forming rhombic crystals, presumably secondary. There is a little muscovite and black opaque grains, apparently iron-oxide."

The observations made along the coast on the stone and coral reefs and on the geographic development of the region are reserved for a separate paper.

RÉSUMÉ OF THE GEOLOGY OF THE COAST SOUTH OF PERNAMBUCO

1. The Tertiary rocks form only a narrow coastal belt between Pernambuco and Maceio; they are nowhere more than about 14 kilometers wide.

2. The underlying crystalline rocks are exposed on the coast at only four places between Pernambuco and Maceio: at Pedras Pretas, Cabo Santo Agostinho, Santo Aleixo, and Pedra do Porto.

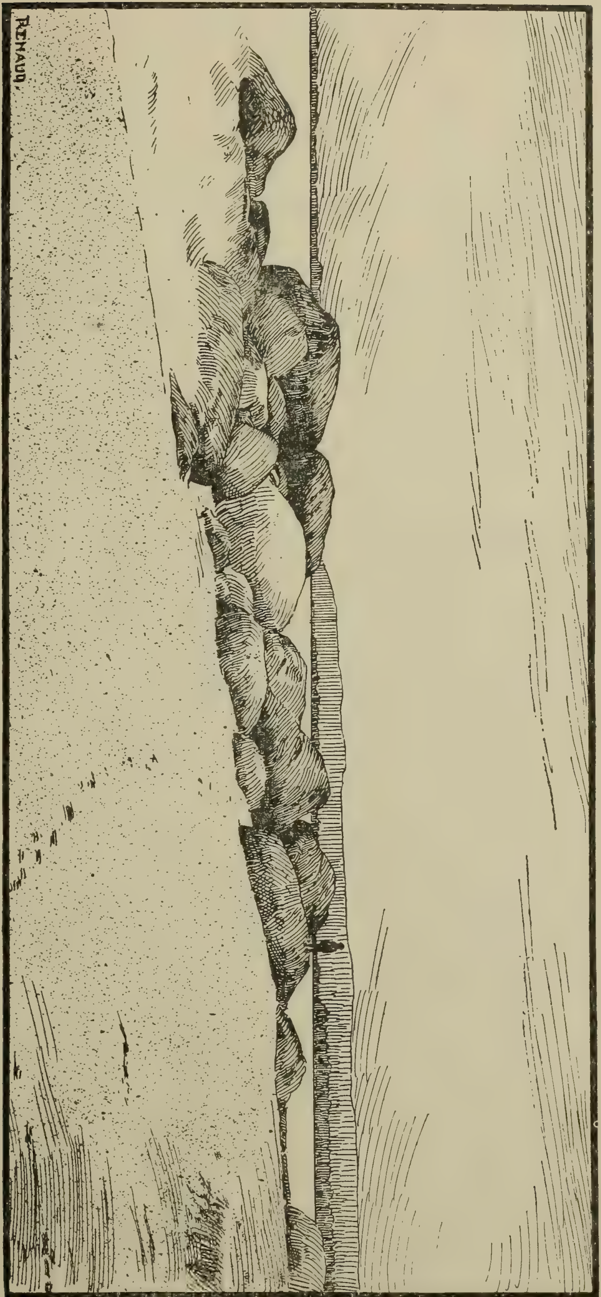


Figure 9.—*Exfoliated Blocks of Biotite-granite on Pedra do Conde Beach.*

3. The rocks at Pedras Pretas are trachytes.

4. Rhyolites form the island of Santo Aleixo, and occur also on the south side of Cabo Santo Agostinho.

5. The rocks of Cabo Santo Agostinho are chiefly granites, granite-porphyries, and diorite.

6. The rocks of Pedra do Porto and Pedra do Conde are granites.

7. The eruptive rocks exposed along the coast are all older than the coast Tertiary deposits.

8. Thus far the Tertiary rocks along the coast have yielded no fossils, and they are assigned to the Tertiary on the theory that they are the same as the fossiliferous beds at Olinda and Maria Farinha, north of the city of Pernambuco.

9. The Tertiary sediments have a maximum thickness along this part of the coast of about 75 meters only.

10. There has been a late elevation of the coast amounting to about 2 meters.

GEOLOGY ALONG THE RECIFE AO SÃO FRANCISCO RAILWAY AND ITS PROLONGATION, SUL DE PERNAMBUCO *

RAILWAY STATIONS AND TOPOGRAPHY ADJACENT THERETO

The following is a list of the stations on the Estrada de Ferro Recife ao São Francisco, with distances and elevations above sealevel, and also of its prolongation, Sul de Pernambuco:

Kilometers.	Station.	Elevation.
		Meters.
0.00	Cinco Pontas (city of Pernambuco)	2.43
2.76	Afogados	4.23
8.72	Boa Viagem	7.75
12.27	Prazeres	9.80
....	Pontezinha	....
24.22	Ilha	2.10
31.51	Cabo	13.30
38.36	Ipojúca	53.50
45.03	Olinda	98.50
51.83	Timbo-Assú	96.00
57.67	Escada	92.44
63.91	Limoeiro	99.60
70.14	Freixeiras	124.87
78.29	Aripibú	119.70
86.87	Ribeirão	95.60
95.78	Gamelleira	90.50
104.02	Cuyambuca	94.40
113.02	Agua Preta	142.86
124.73	Una, or Palmares	120.00

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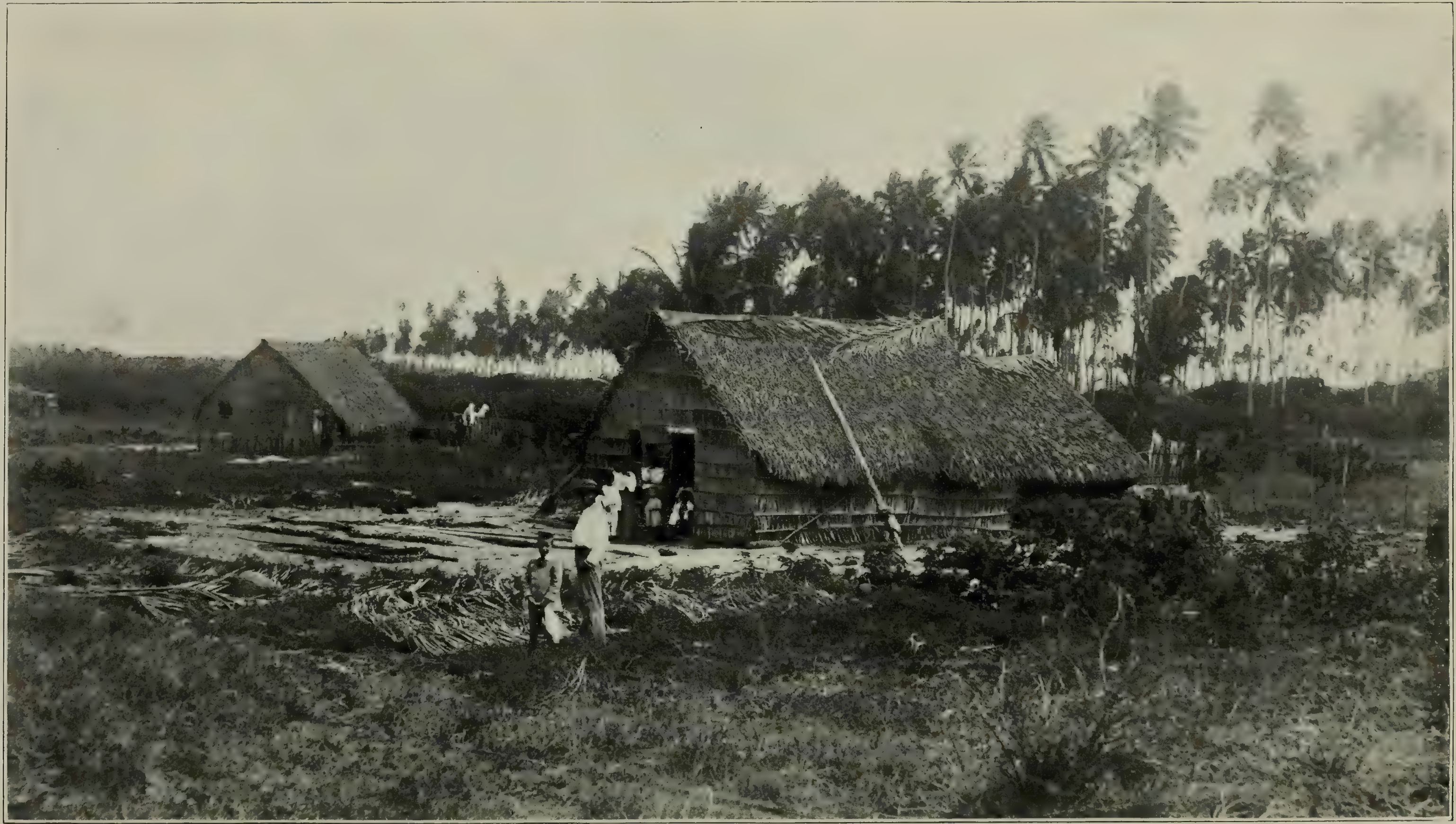
* The notes on the geology along this railway were made in five trips over the line east of Una, three trips over the line east of Glycerio, and wo trips over the line as far as Garanhuns. I am especially indebted to Mr Frank Clemetson, acting superintendent, for his kind cooperation in studying the geology along the line of this railway.



CHARACTERISTIC TOPOGRAPHY AND VEGETATION OF THE PERNAMBUCO COASTAL SAND PLAIN

Estrada de Ferro Sul de Pernambuco

Kilometers.	Station.	Elevation.
		Meters.
129.78	Pirangy	120.00
133.58	Boa Sorte	125.00
142.44	Catende	153.00
155.74	Jaqueira	185.00
158.30	Colonia	189.00
163.82	Marayal	215.60
167.86	Florestal	246.74
174.72	Barra da Jangada	296.00
......	Pery-Pery	......
183.71	São Benedicto	368.60
197.37	Quipapá	427.47
209.65	Agua Branca	563.43
214.46	Glycerio	529.19
227.98	Canhotinho	497.27
242.79	Angelim	647.30
253.52	São João	699.90
271.16	Garanhuns	866.30

The terminal station of the Recife ao São Francisco railway in the city of Pernambuco is called Cinco Pontas. It will be seen from the elevation given in the table above that this station is on the flat plain on which most of the city of Pernambuco is built. Between this place and Afogados the railway runs near the mangrove swamps that cover much of this plain. Afogados, the next station, is on the edge of a mangrove swamp which extends for some kilometers still farther south and west.

About 300 meters northeast of Boa Viagem station the railway passes from the mangrove flats on to the white sandy plain like that about Areias station on the Central railway. This sandy plain extends eastward to the sea. Near the sea it is planted with cocoanut palms. The accompanying illustration gives a good idea of the general appearance of this flat sand-covered plain.

Southwest of the Boa Viagem station the railway continues over the sand plain, but it gradually approaches the Tertiary hills that rise to the northwest of the railway line until they are within a stone's throw of the track.

Prazeres (kilometer 12) is still on the sandy plain, but the hills to the west are only about a kilometer from the line at this place. At Pontezinha there is a small isolated hill about 200 meters west of the station and another a kilometer to the northwest. Half a kilometer beyond Pontezinha the railway crosses the mangrove swamps and Rio Jaboatão; the swamps extend 2 kilometers beyond the river nearly to Ilha station.

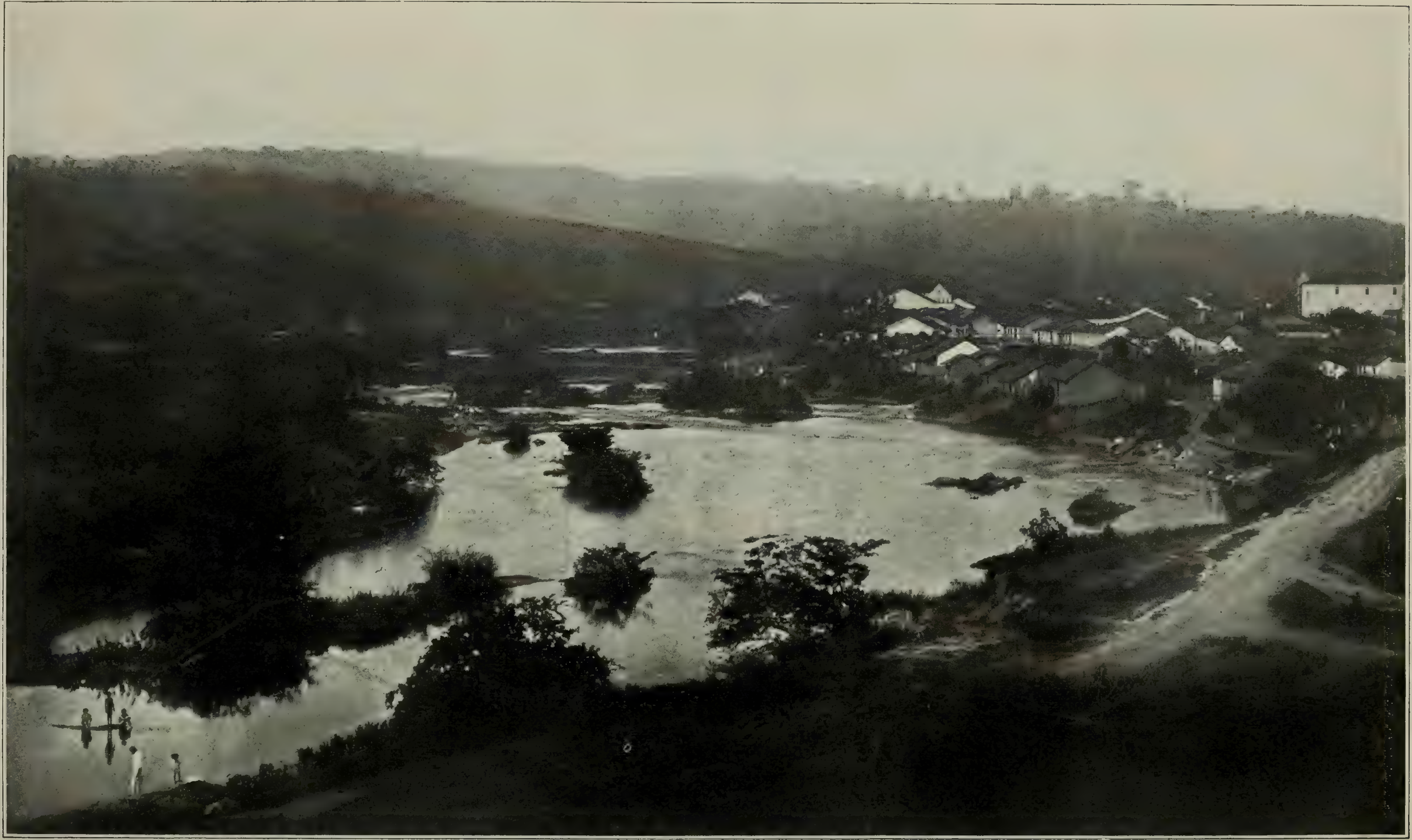
West and northwest of Ilha the Tertiary hills are about half a kilometer from the railway station. Half a kilometer beyond Ilha the hills are about 100 meters northwest of the railway. Where quarries have been opened in these hills the exposures are quite red. Just west of Ilha two streams, the Rios Gurjahú and Pirapáma, join each other, and the hills on the northwest side of the road follow up the left side of the Gurjahú and appear again on the point of land between these two streams. At Cabo (kilometer 31.5; elevation, 13.3 meters) the hills south of the railway are within a stone's throw of the station. At this place the railway leaves the low flat coastal plain and enters the hills. In the outskirts of the city of Cabo there are several cuts, all of them exposing red, yellow, and mottled earth resembling the highly colored Tertiary beds. The rocks, however, are not Tertiary, but crystalline rocks decomposed in place. The hills about Cabo and west of there as far as Boa Sorte are from 50 to 75 meters above the drainage. The region is thus a hilly but not a mountainous one.

ROCK DECOMPOSITION

The granites and gneisses along the railway are usually deeply decomposed, having red, yellow, white, brown, purple, or mottled residuary clays exposed in the railway cuts, and exfoliated boulders of decomposition or rounded bare bosses over the surface of the ground. The depth of the decomposition of the rocks is fairly well shown in a number of the deep cuts along the line of the railway, but it is a notable fact that in many even of the deepest of these cuts the total depth of the decomposition is not shown. A rather remarkable thing about the deep cuts in the residuary earth is that many of the faces exposed in such cuts are nearly vertical, and yet they have stood for many years without falling. The following are some of the deeper cuts where decomposition is well exposed:

One kilometer south of Limoeiro station a cut 14 meters deep has the rock decomposed to the level of the railway track. On the divide east of Palmares cuts 12 meters deep expose red and yellow residuary earth crossed by quartz veins.

At Palmares station (kilometer 124; elevation, 120 meters) there is a cut 6 or 7 meters deep in decomposed crystalline rock. The residuary clay is red and purple and is crossed by the broken quartz veins. The earth of the upper part of the cut is apparently handled material derived from the same decomposed rock, for the quartz that appears as vertical veins in the lower part of the exposure is scattered in subangular fragments along horizontal bands through the upper part of the earth exposed in the cut.



BANDED GNEISS EXPOSED IN THE RIO UNA AT PALMARES, STATE OF PERNAMBUCO

At Pirangý (kilometer 129; elevation, 120 meters) the residual earths are of a deep red color with yellow and purple streaks. Two and a half kilometers west of Pirangý is a cut 12 meters deep in decomposed crystalline rocks.

At and immediately west of Boa Sorte (kilometer 133.5; elevation, 125 meters) the cuts expose decomposed schists with the residuary earths of strikingly brilliant colors—red, white, yellow, and purple.

In the rear of the station at Jaqueira is a cut in yellow and reddish yellow earth. One kilometer east of Colonia are deep cuts in decomposed crystalline rocks. The earths are highly colored.

At Florestal (kilometer 167.8; elevation, 246 meters) there is a cut 12 meters deep in decomposed schist-like rock. The rocks at the bottom of this cut are not decomposed.

Just west of Barra da Jangada station (kilometer 174.7; elevation, 296 meters) is an 8-meter cut in decayed crystalline (schistose) rocks. A hundred meters east of Pery-Perý station decayed crystalline rocks are cut. One hundred and fifty meters farther west there is another cut 10 meters deep.

West of São Benedicto there are several deep cuts nearly all of them in decomposed rocks. West of Quipapá several cuts in decomposed rocks expose kaolin, but the residuary earth is mostly of a red color. On the watershed west of Agua Branca the railway cuts are from 12 to 15 meters deep in decomposed rock cut by quartz veins; the residuary earth is highly colored, and shows marked bedding or the foliated structure of schists. At Glycerio* (kilometer 214; elevation, 529 meters) there is a cut from 9 to 12 meters deep in decomposed crystalline schists. This rock was faulted before it decomposed. The residuary earth is mostly of a purplish color.

STRUCTURAL FEATURES

Returning to Cabo, we may now consider the nature and structural features of the rocks exposed along the line of this railway. From Cabo west and south the road passes over crystalline rocks nearly all the way to Garanhuns, a total distance of 240 kilometers. These rocks seem to be granites, gneisses, and schists, but under the circumstances of profound decomposition in most cases and lack of opportunity for careful examination in others, nothing more than impressions can be set down for many of the exposures. Wherever it was possible to observe it, the approximate direction of the strike of the beds was noted.

Between Timbo Assú (kilometer 51.8) and Escada (kilometer 57.6) many exposures show the rocks to be banded gneisses or schists. This ribbed nature of the rocks is well brought out on weathered exposures. In the Rio Ipojuca, at and near Escada, and at Limoeiro, the exposures show this bedding or schistosity to have an east-west strike. The same east-west strike is shown over the exfoliated bosses half a kilometer east, and again west of Aripibú station (kilometer 78). A short way east of Gamelleira station (kilometer 95.7) the rocks exposed look like granites, and east of Agua Preta (kilometer 113.6) station the rocks are massive like granites. About Palmares (kilometer 124.7) the rocks have a banded structure rather more marked than that of gneiss. At the bridge west of the station the structure is well exposed in the bed and on the sides of Rio Una. The strike here is northeast-southwest. At Pirangý (kilometer 129.7) the rocks are decomposed; the northeast-southwest strike of the beds (or schistosity) is plain.

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* At this place the connection is made with the Alagôas railway to Maceio. For notes on the geology of that line see Proc. Wash. Acad. Sci., vol. ii, pp. 195–201.

Between Bôa Sorte and Catende the strike is northeast-southwest. One kilometer west of Catende the strike is again northeast-southwest. Between Catende and Jaqueira the same strike is exposed in the bed and along the sides of Rio Pirangý.

At Marayal station (kilometer 163.8), 10 meters above the stream, the schistose rocks, with pegmatite dikes, strike north 20 degrees east and dip south 70 degrees east; farther west, however, the strike changes back to northeast-southwest, while at Florestal (kilometer 167.8) the dip is northeast about 30 degrees. Four kilometers above or west of Florestal the rocks in the river bed strike northwest-southeast. Three kilometers east of Barra da Jangada schistose rocks dip northeast 40 degrees; 2 kilometers east of Barra they dip south 30 degrees east. At and just west of São Benedicto (kilometer 183.7) the rocks are schistose, with a north-south strike and an east dip of from 80 to 90 degrees. About a kilometer west of São Benedicto there is either a dike or vein of bluish-black rock exposed in the railway cut. One kilometer east of Quipapá schistose rocks have an east-west strike.

About 150 meters east of Quipapá (kilometer 197.3; elevation, 427 meters) dark mica-schists (?) are well exposed by the track and strike nearly east-west. On the watershed west of Quipapá the rocks have a local strike of nearly north-south and dip east. Two kilometers east of Agua Branca schistose rocks dip east 40 to 45 degrees. The rocks between Quipapá and Agua Branca are faulted and somewhat wrinkled. Between Glycerio and Canhotinho the mica-schists dip to the southeast.

At Canhotinho (kilometer 227.9; elevation, 497 meters) the gneiss is cut by numerous quartz veins. Three hundred meters west of the station the rocks are crystalline schists striking north-south (?) and cut by numerous quartz veins.

Between Canhotinho and Angelim bosses of crystalline rocks are exposed here and there over the campos, and the surfaces show numerous veins of quartz and dikes of pegmatite.

About 5 kilometers west of Canhotinho schists dip south at an angle of 50 degrees. A little farther west there are exposed soft bedded rocks resembling sandstones. Still farther west are schists dipping south 25 degrees west 60 degrees.

Three hundred meters west of Angelim (kilometer 242.7; elevation, 647 meters) are granites and crystalline schists.

Between Angelim and São João there is a line of hills south of the railway, about 100 meters above the railway level, in which the rocks appear to be bedded and to dip north at an angle of about 30 degrees. In the railway cuts the exposures show the schistose rocks for a distance of 2 or 3 kilometers to dip southwest at an angle of about 45 degrees. These rocks are cut by many veins.

At São João (kilometer 253.5; elevation, 699.9 meters) crystalline schists are exposed in the cut just west of the station. They dip northeast.

The rocks at and about Garanhuns are all either gneisses or granites. Most of the surrounding plateau, however, is covered by the products of the decomposition of these rocks.

TOPOGRAPHY OF THE REGION

Some of the topographic features of the region traversed by this railway are worthy of attention. The plateau on which Garanhuns (elevation, 866 meters) stands has an elevation of a little more than 1,000 meters at its western rim at Poço, about 35 kilometers west of the town.* At the west of Cimbres the plateau is said to rise more than 1,000 meters above sealevel. The streams that head in this high region have cut their valleys in this plateau to a depth of 400 and 500 meters. There are no longer mountain chains over the plateau, but neither is the sky-line, as seen from the hills about Garanhuns, a flat or even one. The upper portions of the valleys are rather narrow and steep-sided.

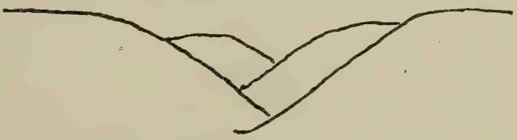

FIGURE 10.—*Profile of the Hills South of Glycerio.*

South of the railway between Garanhuns and São João the following is the profile of the highest hills. These hills are only from 100 to 150 meters high south of the railway half a kilometer from São João.

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* Doctor L. Lombard.

At Canhotinho the railway is in the narrow valley of Canhoto, where the steep hills are about 100 meters high. The hills are much more open than they are from the Rio Canhoto.

WATERWORN GRAVELS

The following notes were made on the occurrence of waterworn materials along the line of this road. In most cases, perhaps in all of them, these waterworn materials clearly belong with the streams near at hand. At Rebeirão a streak of waterworn quartz gravels is exposed 2 meters below the surface of the soil; at Cuyambuca (kilometer 104) a layer of subangular quartz pebbles is shown 2 meters beneath the surface of the yellow soil; 1 kilometer west of Catende waterworn pebbles are exposed 2 meters below the surface; a short way farther west similar gravels are covered by from 3 to 7 meters of soil; about 5 kilometers west of Catende a bed of gravel 1 meter thick is exposed on the north side of the track.

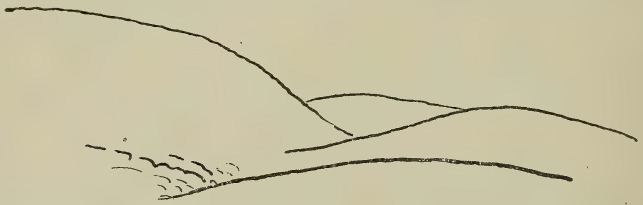

Figure 11.—*Outline of the Hills South of Railway between Garanhuns and Sao Joao.*

At another place the pebbles are from 1 to 2 meters below the surface, but only from 7 to 15 meters above the present stream. Four kilometers east of Quipapá waterworn quartz pebbles are exposed at several places above the present stream, the Pirangý. One and a half and 3 kilometers west of Canhotinho waterworn cobbles are exposed by the railway 10 meters above the stream.

OBSERVATIONS AWAY FROM THE RAILWAY.

These notes have a greater value when taken in connection with observations made off the line of the railway.

Trips have been made by the writer from Palmares north to Bonito, and from Pão d'Assucar, on the Rio São Francisco, to Aguas Bellas, west of Garanhuns.

The whole country about Bonito is of granite, and the Serra da Bonitinho is likewise of granite. There are some striking cases of fluting of gigantic blocks of granite on the highway between Palmares and Bonito.

In the valley below the town of Bonito some of the bare granite bosses show angular inclusions of other and darker rocks.

Between Pão d'Assucar and Aguas Bellas the rocks are granites and gneisses, with some highly metamorphosed rocks The latter include inconspicuous beds of crystalline limestone in the Serra dos Meninos near Aguas Bellas. The granitic rocks were observed at Lagoa da Lagea, 8 leagues east of Aguas Bellas, and at Pedra Pintada, 12 leagues west of Garanhuns.*

Two interesting papers have been likewise published by Doctor L. Lombard on the geology of the interior of the state of Pernambuco, and inasmuch as Doctor Lombard's papers were published only in Portuguese, where they are inaccessible to geologists, I give here his conclusions so far as they relate to the geology of the state of Pernambuco in the vicinity of the Recife ao São Francisco railway.

One of Doctor Lombard's papers † contain the results of two months' work in the region south of Garanhuns, and covers an area of about 3,500 square kilometers. He summarizes the geology of the region as follows:

> "The terranes of this region belong to the lower part of the primitive terrane here represented by gneiss in contact with granite. Mica schists are rare. The only ones I found are on Rio Salgadinho, where they resemble a gneiss poor in feldspar. The gneiss and granite merge together without exhibiting any sharp lines of distinction. Outcrops of later basic eruptive rocks are rare, and the disturbances of the beds of gneiss were caused by eruptions of granite and perhaps of granolite."

Doctor Lombard's second paper ‡ treats of the region between Garanhuns and Buique and of the country around Buique. The area covered by his map is about 5,000 square kilometers.

He found the region between Garanhuns and Buique to be of granite and gneiss. Descending the Serra de São José, the gneiss dips northeast at an angle of 20 degrees. In the basin of the Rio Ypanema the rocks are more granitic. Near Rio Cordeiro a dike of diabase was seen. The Serra de Buique is of granite, but along the southeast side of the Serra there are limestones. Nothing is told of the geologic position of these limestones. The mountain masses and the plateau west, north, and northeast of Buique are of sandstone resting on granite. The mountains known as Coqueiro, São José, Catimbao, Quyri d'Alho, Andorinho, and Chapeo are all of sandstone. These sandstones dip toward the southeast at an angle of from 10 to 15 degrees.

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* Further notes on the region about Aguas Bellas are given in the Amer. Jour. Sci. for Feb., 1902.

† Relatorio sobre a exploração da parte sul do Estado de Pernambuco entre Palmares e Bom Conselho. Por L. Lombard. Recife, 1895, being pages 51-62 of the Relatorio apresentado ao Exm. Sr. Governador do Estado . . . pelo Dr Rodolpho Galvão, Secretario dos Negocios da Industria. Recife, 1895.

‡ Relatorio sobre a exploração mineralogica de Garanhuns á Buique e da zona salitrosa de Buique. Por L. Lombard ; pages 123-140 of the report above cited. Recife, 1895.

The sandstones contain mica, waterworn quartz pebbles, and bits of kaolin. They yield some salt and saltpeter, which are extracted by leaching, and certain organic substances the character of which was not determined.* Doctor Lombard regards these sandstones as of "primitive or pre-Cambrian" age.

In the absence of fossils it is hardly worth while to speculate on their age. It seems much more probable, however, that these sediments belong to the great Cretaceous area that covers a large part of the interior of Piauhy, Ceará, Parahyba, and Pernambuco. The elevation of the Buique sandstones (between 800 and 900 meters above tide) appears to make it improbable that they belong to the Tertiary.

L. E. Dombre, a French engineer connected with the department of public works of the province of Pernambuco, traveled through the interior of that province in the years of 1874 and 1875, and in his letters to the director gave many valuable notes upon the geology of the region visited.†

Dombre went as far west as Floresta, but reference is here made only to his notes upon on the geology in the vicinity of Recife ao São Francisco railway.

Of the general character of the geology Mr Dombre says ‡ that the few sedimentary basins seen by him are completely metamorphosed and contain no fossils. He makes no mention, however, of the location of such sedimentary rocks.

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* This organic matter is known in the region in which it is found as *borra*. A sample of it was given me by Doctor Lombard, and was submitted to Dr J. M. Stillman, the head professor of chemistry at Stanford University, who gives me the following as the results of his chemical examination :

"The substance submitted under the name of *borra* appears to be largely earth, sand, and gravel cemented together by or permeated with a substance or mixture of substances of organic origin and of deep chocolate brown color. The organic matter is of that class of substances which have been at times called mineral resins—*Erdharze*—for want of more definite names.

"The *borra* is brittle and hard, does not melt or soften appreciably by heating. At high temperatures it gives off vapors of pungent odor and burns with a yellow flame, leaving an earthy residue in the form of the original mass and composing by far the greater part of the entire mass. Rubbed to a fine powder and extracted with alcohol and ether the borra gives a small quantity of colorless extract of a bitter taste. The residue from the alcohol-ether extraction when treated with caustic soda solution gives a solution of dark brown color, reprecipitated on neutralizing with acids as a brown resinous mass, insoluble in water, and but slightly soluble in alcohol, to which, however, it imparts a color by partial solution. That portion of the organic matter not dissolved by hot caustic soda was in the form of a dark brown pulverulent mass mixed with inorganic residue, and is not easily soluble in the common solvents. In concentrated sulphuric acid it dissolves at least partly with a dark brown color.

"My interpretation of the above is that the organic matter in the *borra* is a mixture of substances largely oxygenated and of faintly acid character, such as are often characterized as 'mineral resins,' or as are intermediate between these and the so-called humus substances. The organic matter is present in too small quantity and too difficult to separate from its earthy admixture to be more definitely characterized."

† Viagens do Engenheiro Dombre do Interior da Provincia de Pernambuco em 1874 e 1875 In French and Portuguese 12°, 86 pp. Recife, 1893.

‡ Loc. cit., p. 36.

The rocks about Panellas, north of Quipapá, he found to be fine-grained gray granites. At Pesqueira, northwest of Garanhuns, he found granites, and the Serra de Ororobá, near Cimbres, he found to be of granite exposed in solid rounded peaks.*

Between Pesqueira and São Bento he found only granites.† In the vicinity of Bom Conselho (Papacáça) he found "everywhere the same terrane of granite or porphyry,"‡ while at Ipueiras, southwest of Bom Conselho, he reports gneiss and schist and an "irregular bed of white crystalline limestone."

RÉSUMÉ OF THE GEOLOGY ALONG THE RECIFE AO SÃO FRANCISCO RAILWAY

The crystalline rocks through the region of the Recife ao São Francisco railway are much faulted. These rocks are chiefly granite, gneisses, and schists.

West of Canhotinho a few exposures look like sedimentary rocks, but these beds were not carefully examined and it may be that the appearance of bedding is due to metamorphism.

The strike of the beds (or the schistosity ?) is somewhat constant along the northeastern half of the railway line, but farther west the dip and strike vary greatly in amount and direction. These changes are enough to show that no trustworthy conclusions can be drawn from similarity or dissimilarity of dip and strike in widely separated districts in the Paleozoic regions of Brazil.

It is still supposed by some people living in the state of Pernambuco that the rounded bosses of granite and the great rounded boulders found over the hilltops along the line of this railway are of glacial origin. This is quite erroneous. The theory at one time advocated by Louis Agassiz and by Belt that this part of South America was covered by ice during the glacial period has been shown to be untenable. These particular boulders originated where they now lie, unless they may in some instances have rolled down the hillsides. Such boulders occur between Cabo and Ipojúca, 300 meters east of Olinda station (kilometers, 45), about Timbo-Assú, and at many other points along the railway.

Decomposition of the rocks is widespread, but the depths of the decomposition exposed in the railway cuts along this railway does not exceed 20 meters.

The sedimentary beds north and west of Buique have yielded no fossils, but it seems probable that they are a part of the Cretaceous area of the interior of Piauhý and Ceará.

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* Loc. cit., p. 81.

† Loc. cit., p. 83.

‡ Loc. cit., p. 37.

In comparing the geology and geography along this railway with that along the Estrada Central, we find these two railways crossing similar belts as follows:

1. The low coastal plain of mangrove swamps and the sandy plain of Areias and Bôa Viagem.
2. The narrow line of Tertiary hills ending near Tigipió, on the Central, and between Ilha and Cabo, on the Recife ao São Francisco line.
3. A belt of low hills of crystalline rocks ending on the Central road at the base of the Serra da Russa, and on the Recife ao São Francisco line near Canhotinho, or possibly somewhat farther east.
4. An elevated region from which Paleozoic (?) sediments have been partly removed. On the Central railway this region begins with the Serra da Russa; on the Recife ao São Francisco it begins near Canhotinho, and, extending westward, forms the mountain tops to and beyond Aguas Bellas.

Geology along the Estrada de Ferro Central de Pernambuco*

RAILROAD STATIONS

The following is a list of the stations, distances, and elevations on the Estrada de Ferro Central de Pernambuco:

Kilometers from the Central, Pernambuco.	Station.	Elevation above tide.
		Meters.
0	Central (Pernambuco)	2.4
6	Areias	5.0
8	Tigipió	11.0
..	Socorro	....
16	Jaboatão	45.0
27	Morenos	85.6
38	Tapera	155.0
51	Victoria	146.0
64	Francisco Glycerio	194.8
72	Russinha	308 8
89	Gravatá	446.0
112	Bezerros	459.0
127	Gonçalves Ferreira	509.1
136	Caruarú	537.7
161	São Caetano	548.6
180	Antonio Olyntho	565.0

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* For the privilege of examining the geology along this railway I am indebted to Dr Antonio Pai Pires Ferreira, the obliging director of the railway at the time of my visit. Doctor Ferreira has also kindly furnished me with a large scale map of the line of the railway, and has sent me specimens of the São Caetano marble.

TOPOGRAPHY IN DETAIL AND THE ROCK EXPOSURES

From the central station, in the city of Pernambuco, to within half a kilometer of Areias station, the railway passes over a flat country, much of it covered with mangrove swamps. Half a kilometer east of Areias the road cuts a sand bank 5 or 6 meters in height. This bank is the margin of the flat sand-covered plain around Areias station. A few hundred meters east of Areias station the railway crosses a narrow steep-sided, flat-bottomed valley. West of Areias and east of Tigipió station is another valley of similar shape, draining into the Capibaribe. The valleys around the margin of this sand plain are dendritic in form and belong to a single type. The following sketch shows a cross-section of one of them:

These peculiar features are interpreted to mean that the Areias plain formerly stood at a greater elevation than at present, and at the time of this elevation steep-sided gullies or narrow winding valleys were cut by the streams around the margins of the plain. A subsequent depression carried the bottoms of these narrow valleys beneath the salt water, whereupon they were immediately silted up.

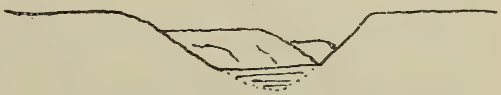

Figure 12.—*Profile of the Hills at Areias.*

Three hundred meters west of Areias station the railway line cuts the colored Tertiary sedimentary beds. These beds are red; most of them contain small quartz pebbles that are scattered through the strata rather than arranged in well-marked bands. At Tigipió a cut on the north side of the road shows waterworn pebbles in approximately horizontal bands.

At this same station the bottom of the creek valley is flat, as if belonging to the dendritic group around the Areias plain. The low hills east of Tigipió are of about even height. West of Tigipió the hills are at once higher—perhaps 70 meters higher than the railway. The Tertiary beds, such as are exposed at Dois Irmãos, Caxangá, and Macacos, on the north side of the open plain about Pernambuco, are but little exposed along the line of the Estrada Central. Beginning a short distance west of Areias, they are exposed to and at Tigipió station and end 2 or 3 kilometers west of there; even so they appear mostly in the tops of the hills at this western end of the beds. Two kilometers west of Tigipió a railway cut exposes a horizontal bed of waterworn gravel. Between 2 and 3 kilometers west of Tigipió decayed crystalline rocks are exposed in a cut on the south side of the track. These rocks, however, are exposed only in the lower portion of the cut. They are overlain by a bed, about half a meter in thickness, of coarse, waterworn quartz gravels, with from 1 to 2 meters of soil above it.

From this point westward the cuts expose no more Tertiary beds. Before reaching Jaboatão there are many exposures of decomposed gneiss or granite, in which are hard unaffected cores or boulders of decomposition. One of the largest of these cuts is about 3 kilometers east of Jaboatão. East of the cut there are exposures of granite in the valley. One kilometer east of Jaboatão there is a cut 12 meters deep. This exposes red residuary soil with large blocks of undecomposed gneiss scattered through it. Immediately east of Jaboatão station is a cut about 10 meters deep in a decayed gneissoid rock. At this station there are many exposures of crystalline rocks in the bed of the Rio Jaboatão. A little more than half a kilometer west of the station is a cut 10 meters deep. Very few of these cuts expose solid rock even at the bottom; but most of them still have some boulders of the unaltered rock left behind.

Three or 4 kilometers west of Jaboatão the railway cuts expose beds of subangular gravels 0.2 meter or 0.3 meter thick. These cuts, however, are not in the crests of the ridges, but more than halfway down their slopes. It seems probable that the gravels are left by the streams cutting their way downward, and that they do not belong to the Tertiary gravel sheets.

About 1 kilometer east of Morenos station (kilometer 27) there is a cut 10 meters deep, and several others not so deep, in red residuary earth. At Morenos station the Rio Jaboatão flows over and between blocks of granite. Five kilometers west of Morenos small fluted bosses of gneiss are exposed in the fields.

Between Morenos (kilometer 27) and Tapéra (kilometer 38) there are several cuts 10 meters deep. In some of them the rocks are decomposed down to the level of the railway track, while in others there remain here and there undecomposed lumps of the original crystalline rock.

Where the cuts expose the rock decayed in place along this portion of the line the residual clays are red, yellow, brown, and mottled, but red is the predominating color.

Three or 4 kilometers west of Tapéra the first bedded or foliated rocks were seen. East of the watershed between Tapéra (kilometer 38) and Victoria (kilometer 51) these rocks look like gneiss, with a general east-west strike. West of the watershed and to within 3 kilometers of Victoria station the rocks are schists and shales standing at high angles (60 to 80 degrees). East of Victoria for about 3 kilometers the rocks are more like granites. Immediately east of Victoria station is a cut about 8 meters deep. The bottom of the cut is in decomposed crystalline rocks with quartz veins. Above this is a bed from 0.1 to 1.0 meter thick of heavy waterworn pebbles, and above this is from 0.5 to 2 meters of soil. It is to be observed that Victoria has an elevation above tide of 146 meters, and the gravel beds in the vicinity of the larger streams are provisionally referred to fluviatile rather than to marine origin. West of Victoria the rocks still appear to be more or less schistose.

At Francisco Glycerio station (kilometer 64; elevation, 194.8 meters) the railway cuts in red clay expose a few waterworn quartz pebbles at the line of the junction between the soil and the hard rocks beneath. In the vicinity of this station a rather flat plain opens northward, while to the south and west rise mountains locally known as the Serra da Russa, with a maximum elevation of 503 meters near the railway line where it crosses into the valley of Rio Ipojúca. These mountains, however, are but the eastern and northern margin of the high and hilly plateau of the upper Ipojúca drainage. West of Francisco Glycerio the railway ascends the escarpment of the great plateau. Between Francisco Glycerio and Russinha, at an elevation of about 250 meters, the brilliant red and yellow colors so characteristic east of this place appear to end. West of here, also, the decomposition of the rocks does not seem to be so deep or so widespread.

Immediately west of Glycerio the country is soil-covered, and more than half of it is under cultivation. There are a few exposures of rock on the hillsides and in the creek beds. There is a rather persistent but in places pockety line of pebbles exposed in the cuts along this part of the railway. It is generally at the junction of the soil and the undecayed rocks beneath, and appears to be related genetically to the former but not far removed drainage of the region. The individual blocks of these gravels are often as large as a man's head.

Along the next 3 to 5 kilometers east of Russinha the rocks look like dark, very micaceous gneisses; they are cut by a few quartz veins and are deeply decomposed.

As one goes westward, Russinha (kilometer 72; elevation, 308.8) is the last station on the railway before reaching the crest of the Serra da Russa. A short distance west of that station the line crosses the watershed between the Rio Capibaribe drainage and that of Rio Ipojúca. West of Russinha there are many deep cuts along the line of the road that make excellent exposures of the geology; some of these cuts are as much as 30 meters deep measured on the upper slopes, and many of them are 15 meters deep. There are, besides, several tunnels in which the rocks are so solid that the tunnels do not require to be lined save at their mouths. One tunnel was being lined, however, at the time of my visit. Some of the rocks in these cuts are more evenly bedded, as if they were shales and sandstones, while others are schistose or gneissic. They are much jointed and but a little wrinkled, and stand at high angles, 70 to 80 degrees, with a south (?) dip. In places they appear to be crushed and faulted.

Between Russinha and the tunnels the cuts nearer the station expose rather darker, more micaceous, and more decomposed rocks than those higher up the mountains. From near the top of the mountain there is a magnificent view toward the northeast and overlooking the hilly valley of the Capibaribe. Between the summit and Rio Ipojúca are some exposures of pinkish colored shales. After passing the divide of the Serra da Russa there is but a slight descent to Gravatá station, on Rio Ipojúca, in the bottom of the valley to the southwest of the mountain. Thus the Ipojúca at this station is not in a valley like that at Victoria or at Escada, but it flows through a wide, open, flat valley near the edge of a mountainous plateau having an elevation of 500 meters or more above the sea.

Two hundred meters east of Gravatá station (kilometer 89; elevation, 446 meters) there is a good exposure of the shales in a long shallow cut. These rocks are clearly bedded, and some of them have the appearance of altered silicious sediments like novaculites or diatomaceous shales. Under a microscope of low power they seem to be filled with elongated or lens-shaped grains of quartz or opal. They have a south dip of about 70 degrees.

The mountains seen south of Gravatá have exposures of bare rocks about their summits. Three hundred meters west of Gravatá, again 1½ kilometers west of Gravatá, and again 3 or 4 kilometers west of the same station are cuts along the railway, in which bedded rocks—schists or shales—are exposed with high (70 to 80 degrees) south dips.

A belt of gneiss-like, dark banded rocks, 2 or 3 kilometers wide, follows. From 1 to 2 kilometers east of Bezerros station and south of the river schistose rocks are exposed mostly with a south dip. There are several bosses and exfoliated masses of gneiss just east of Bezerros. At several places waterworn pebbles are exposed along the railway, but these exposures are all near the Rio Ipojúca. At Bezerros (kilometer 112; elevation, 459 meters) a cut in the rocks opposite the station exposes hornblende-schists crossed by large veins of pink feldspar. These schists have a south dip of only about 30 degrees.

South of Bezerros the Serra Vermelha is in full view. It appears to rise about 200 meters above the plateau. Bare rocks are exposed here and there over its sides, resembling granite or gneiss bosses. Dombre reports a bed of hematite iron ore in the Serra Negra, 2 leagues north of Bezerros.

Between Bezerros and Gonçalves Ferreira the railway appears to cross and recross the contact between coarse grained granites and schists. The dip of the schists changes, but it is always high, sometimes apparently on end, with an east-west strike. One of the cuts, 6 meters deep, exposes schists beautifully for several hundred meters.

At Gonçalves Ferreira station (kilometer 127; elevation, 509 meters) the rocks continue to strike east-west. The mountains about 2 kilometers north of the railway station expose enormous and beautifully exfoliated boulders and bosses of massive granite with black inclusions. One of these large blocks is beautifully fluted. From the railway station this mountain, known as the Serra de Imburana, is an impressive sight.

Where the railway goes round the west end of the mountain, there is exposed near the track a layer of coarse waterworn pebbles varying in size from 5 to 20 centimeters in diameter. These pebbles appear to be one of many separate patches rather than part of a sheet, though there may be such a sheet over the Caruarú plain. About 2 kilometers west of Gonçalves Ferreira, at the foot of the Serra Imburána, there is a fine exposure of a very dark gneiss with large pink feldspars.

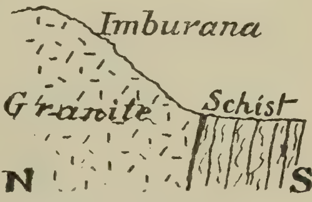

Figure 13.—*Apparent Relation of Schists and Granites East of Caruarú.*

Three kilometers east of Caruarú the railway passes from schists to granites; the schists appear to dip north at an angle of 80 degrees, as if passing beneath the granite mountain, Serra Imburána. Immediately east of Caruarú the granites contain aplite dikes.

Caruarú station (kilometer 139; elevation, 537.7 meters) stands on a flat plain near the base of a conical granite hill. In sight of the town both north and south are ranges of mountains approximately parallel with the Ipojúca valley and with the general direction of the railway. The granite peak at Caruarú exposes in places exfoliated blocks and bosses, but in July, 1899, the greater part of it was covered with vegetation. The rocks at the base of the peak are coarse grained granites, and these cover the country for miles around. The plain west of Caruarú is covered with a thin coating of waterworn quartz pebbles. There are no heavy forests hereabout; the vegetation is low and scrubby, probably owing to the droughts to which this region is sometimes subjected.

West of Caruarú there are many good exposures along the railway of coarse grained and beautiful pink granites, popularly known as "Scotch granite." These granites are cut here and there by big quartz veins and aplite dikes; in places the rocks are gneissic, occasionally they are decomposed.

Near São Caetano schists alternate with the granites, and the schists appear to form a belt lying north of the granites of Caruarú but south of those of the Serra Imburána. West and south of São Caetano the rocks are more like gneisses, but they show the banded structure of schists. West of São Caetano for 3 or 4 kilometers the dip of the rocks is south and about 65 to 70 degrees; farther west the dip is north and about 80 degrees.

There are limestones in the vicinity of São Caetano, but I was unable to visit the quarries. Dombre saw these deposits and states that they form a bed having an east-west strike at two outcrops, but he does not mention the thickness of the rocks.*

Through the courtesy of Dr Antonio Pai Pires Ferreira, the director of the Estrada de Ferro Central, I received a specimen of the limestone from the quarries south of São Caetano. It is a beautiful fine grained marble, capable of a high polish.

The following analysis by Professor L. R. Lennox shows it to be a remarkably pure limestone:

Analysis of the São Caetano Marble

	Per cent.
Silica (SiO_2)	.14
Oxide of iron and alumina (Fe_2O_3 and Al_2O_3)	.14
Lime (CaO)	55.19
Magnesia (MgO)	.40
Carbonic acid (CO_2)	43.80
Phosphoric acid not determined	
	99.67

Antonio Olyntho (kilometers 180), the last station on this line, is likewise the highest, and has an elevation of 565 meters above sealevel. Before the arrival of the railway this place was known as Curralinho. The country around is a part of the elevated plateau extending west from the Serra da Russa. The valley of the Ipojúca is here a rolling flat valley, with mountains visible on the horizon to the north and to the southeast.

There are several good exposures of rocks at the station and north of the Y, and also along the railway track east of the station. In the cut north of the Y there are five or six faults from 2 to 4 meters apart and striking approximately east-west. The rocks here dip north at a high angle. The notes made at Antonio Olyntho station say that "the schistose metamorphic rocks have shales interbedded with them." But the metamorphic rocks appear to be tuffs, so that the series was probably originally deposited in water where clays alternated with the volcanic ejectamenta that form the feldspathic beds. A prominent feature of these bedded rocks is a felted appearance that is characteristic of the old Paleozoic rocks through the highlands of Brazil. In the felted silicious schists are occasional lenses or bands of flint or chalcedony closely resembling novaculites, some of them more than a meter in length and 20 centimeters wide; one was noted having a length of 3 meters and a width of 2 centimeters. These flints are partly surrounded by and partly penetrated by pink feldspars. The schists vary in color from nearly black where they are unweathered to gray where they are weathered. The black ones are exceedingly hard. The pink feldspars are characteristic of all or nearly all of them, and many of them contain quartz lenses.

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* Viagens do Engenheiro Dombre ao Interior da Provincia de Pernambuco em 1874 e 1875. Recife, 1893, p. 14.

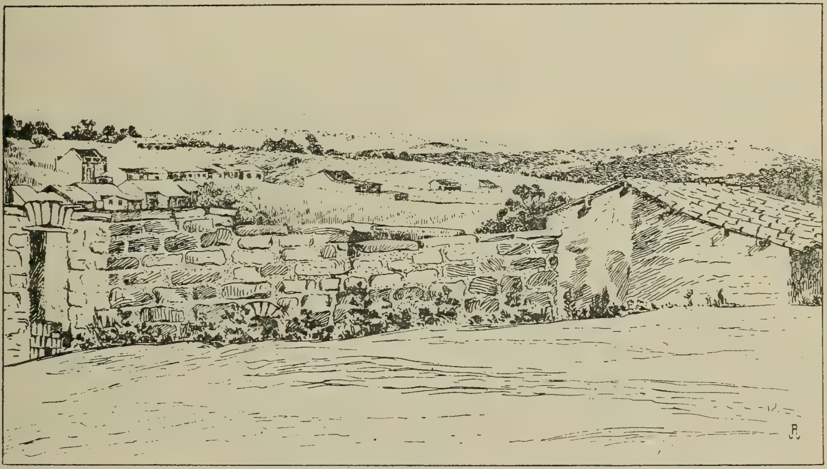

FIGURE 14.—*Looking west from Antonio Olyntho.*

All of these bedded rocks are much jointed, the clean, smooth joints cutting for the most part square across the beds. The joints are from 1 centimeter to 15 centimeters apart.

The schistose rocks about Antonio Olyntho are slickensided. This fact, together with the faults exposed at Antonio Olyntho and the general structure, so far as it is visible between the Serra da Russa and the west end of the valley, lead to the conclusion that the region is much faulted, especially along the east-west belt crossed by the railway between Caruarú and Antonio Olyntho.

According to the observations of Dombre, the granitic rocks found about Bezerros continue to São Bento, about 40 kilometers south and a little west of Antonio Olyntho, and granites are also reported by him between São Bento and Pesqueira farther west.

Since the preceding pages were written sections of the jointed and felted rocks found near Antonio Olyntho were submitted to Dr J. P. Iddings, who kindly writes of them as follows:

"The three sections sent me appear to come from the same rock. Under the microscope it is seen to be a metamorphosed granitic rock, or possibly granitic porphyry or a rhyolite. It consists of phenocrysts or the remnants of potash feldspar in a micro-granular groundmass of quartz and unstriated alkali feldspar. There is a sheared, streaked, flow structure, and it is plainly seen that there has been crushing and shearing and recrystallization of the minute crushed particles.

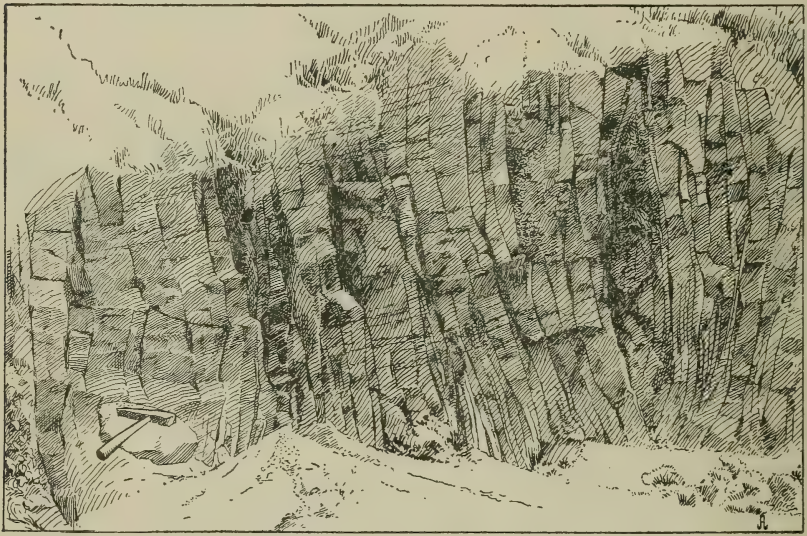

FIGURE 15.—*Jointed and metamorphosed Rhyolite Tuff near Antonio Olyntho.*

The large feldspars are partly shattered and split apart and the spaces between filled with granular quartz. The feldspars are microcline by the straining of orthoclase, the twinning being most noticeable where the stress appears to have been great. The minute grains of feldspar are unstriated, with low refraction, therefore alkali, presumably orthoclase (?) (unstriated microcline). In places the large untwinned feldspars are streaked with another unstriated feldspar in a perthitic manner. The grains of quartz and feldspar in groundmass are not evenly distributed, but are in streaked patches of many feldspar grains and many of quartz, suggesting that the original rock was a fine-grained granite, rather than a porphyry.

"There is very little of other minerals present. Small particles of colorless and yellowish muscovite in streaks, small crushed apatites, little crushed magnetite, little (?) hornblende, pale green. I should think the rock a crushed orthoclase granite, having very little mica and little else."

It should be added that I felt convinced while looking at them in the field that many of the rocks in and west of the Serra da Russa were metamorphosed sedimentary beds. The rock described by Mr Iddings belongs to what I supposed to be a metamorphosed tuff of some kind. Mr Iddings tells me that this is not impossible, but that there is nothing in the slides alone to show it.

I am further induced to think these rocks are rhyolitic tuffs partly by their constant evidence of bedding, by their association with shales, and by the agreement of their strike with the strike of the limestones at São Caetano, as reported by Dombre.

CONCLUSIONS REGARDING GEOLOGY ALONG THE CENTRAL RAILWAY OF PERNAMBUCO

1. The Tertiary (?) beds are exposed along the Estrada Central only to kilometer 13 from the Pernambuco end of the line.
2. The topography about Areias and Tigipió suggests a late elevation and a still later depression of the region.
3. Whether the granites are older or newer than the schists is not clear from anything observed along this geologic section.
4. The colors of the residuary clays are much more brilliant from just west of Francisco Glycerio eastward—that is, from sealevel up to an elevation of about 200 meters—than they are at a greater elevation and west of there.
5. West of the Tertiary area the railway passes over granites, gneisses, and schists. From Russinha westward there are a few places at which stratified rocks are exposed. Some of these resemble altered tuffs and some are shales.
6. The bedded rocks include remarkably pure limestones (marbles) south of São Caetano, and these marbles also have an east-west strike.
7. Some of the metamorphosed beds have the felted appearance characteristic of certain Paleozoic rocks of the Minas Geraes highlands.
8. The region west of the Serra da Russa seems to be much faulted, the faults following the east-west strike of the rocks.

GEOLOGY ALONG THE GREAT WESTERN RAILWAY FROM PERNAMBUCO TO TIMBAUBA *

RAILWAY STATIONS

The following is a list of the stations, with distances and elevations:

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* The author is indebted to the Pernambuco officers of the railway company for free transportation over the line for himself and five assistants and for every courtesy and attention that could add to the pleasure and interest of the trip.

Kilometers.	Station.	Elevation above flood tide.*
		Meters.
0.000	Brum	1.24
3.150	Encruzilhada	4.04
6.550	Officinas	10.04
13.750	Macacos	47.24
18.376	Camaragibe	35.24
25.175	São Lourenço	31.24
30.120	Tiuma	44.24
33.000	Santa Rita	53.94
48.822	Páo d'Alho	69.54
59.875	Carpina	182.64
67.243	Tracunhaem	90.74
72.944	Nazareth	57.84
80.000	Junco	....
84.144	Lagoa Secca	46.24
91.244	Barauna	73.64
97.244	Alliança	59.24
107.600	Pureza	70.24
118.000	Timbauba	100.74

TOPOGRAPHY AND ROCK EXPOSURES ADJACENT TO STATIONS

The Recife or Pernambuco end of the Great Western of Brazil railway is at Brum, near the old Dutch fort between the city of Recife and Olinda. Brum stands upon a sand spit that rises but little more than a meter above high-tide level. The land is all low, sandy, and flat from Brum to Encruzilhada, 3 kilometers out. Two and a half kilometers beyond Encruzilhada the line of the railway comes to the foot of the Tertiary hills of highly colored sedimentary rocks. At Arrayal the hills east and north of the road are from 30 to 50 meters above the flat coastal plain. About one and a half kilometers beyond † Arrayal the railway leaves the plain and ascends through many cuts in the soft particolored Tertiary beds. The rocks exposed in these cuts are red, brown, purple, yellow, gray, white, and mottled. The beds are approximately horizontal, and the materials are mostly rather fine sediments, with here and there coarse waterworn gravels.

At Macacos station (kilometer 13.7) the elevation of the road is 47 meters, and the big cut near the station is 20 meters deep, all of it being

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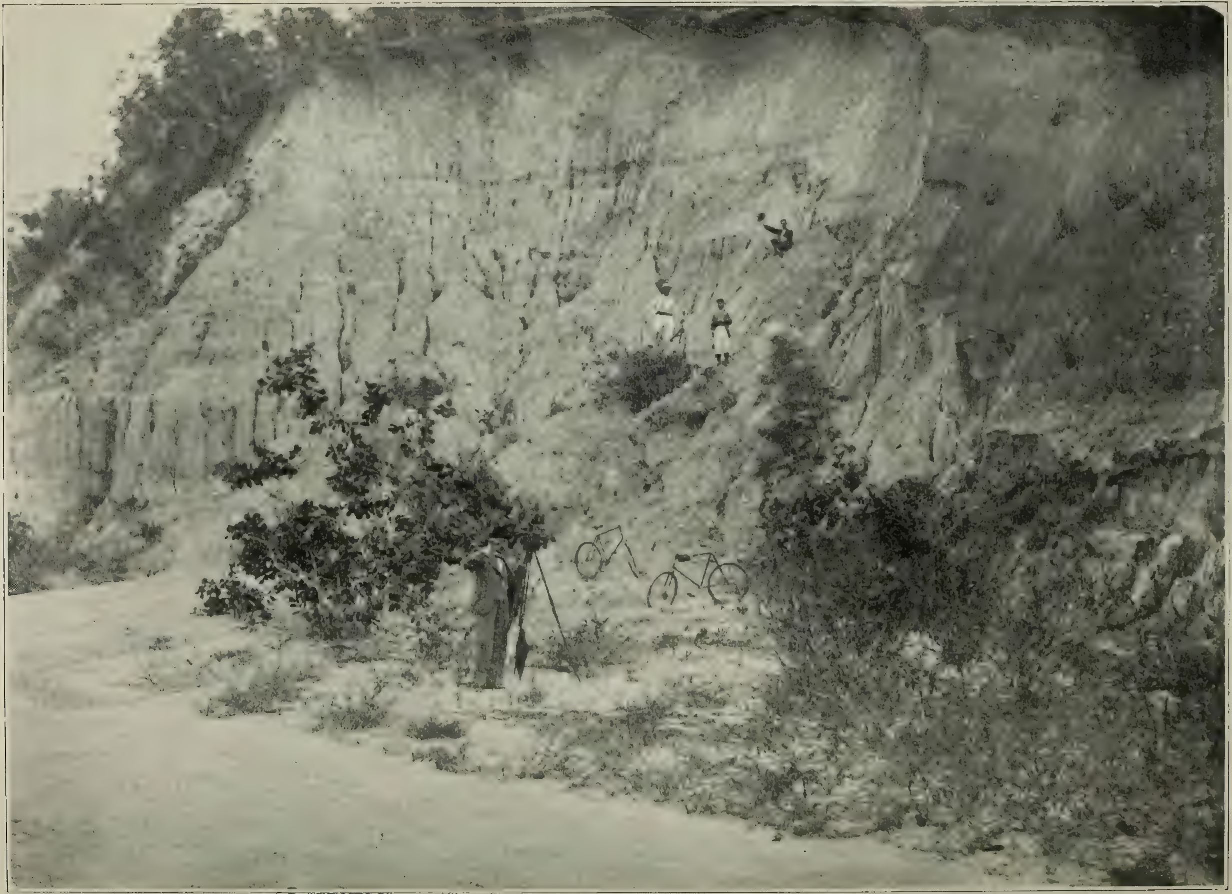
* The elevations as kindly furnished me by Mr John A. Lorimer, of the railway company, are referred to the bench-mark at the Arsenal de Marinha, at Pernambuco. This station is said to be 8.76 meters below flood tide. All elevations are referred to high tide by subtracting 8.76 meters from the elevations as used by the railway.

† These notes are written as if made on the outward trip; "beyond" a given point, therefore, always means along the line of the road and away from the Pernambuco end.



TERTIARY SEDIMENTS AT DOIS IRMÃOS NEAR PERNAMBUCO

in the particolored Tertiary beds. These beds were examined for fossils, but none were found.

It should be mentioned in this connection that the reservoir at Dois Irmãos, northwest of the city of Pernambuco, is on one of these Tertiary hills, and that the summit of that particular hill has an elevation of 81 meters above tide.

The cuts at and near Macacos have given the railway company much trouble on account of the landslips that often occur in them during the rainy seasons. The white layers are especially liable to cause these landslides. This is due to the fact that these white beds are mostly kaolin deposited from the decomposed feldspars of the underlying crystalline rocks. When these kaolins become wet they are exceedingly slippery.

About half a kilometer beyond Macacos, where erosion has cut deeply into the Tertiary sediments, the underlying granite is exposed in patches. One kilometer beyond Macacos the granite (or gneiss) is exposed by the railway track.

The exposures of the old crystalline rocks show that their upper surface is quite uneven, for the Tertiary sediments are exposed in many places at lower as well as at higher elevations than the granites.

At Camaragibe (kilometer 18.3; elevation, 35.24 meters), north of the track and half a kilometer beyond that station, granite is exposed. The Tertiary continues a little beyond this point, though it is more or less patchy north of Camaragibe.

The railway enters the valley of Rio Capibaribe at Camaragibe and follows it up to Páo d'Alho. It is worthy of note that the line of the railway, instead of following up the valley of Rio Capibaribe, leaves the plain through which that stream enters the ocean, passes through expensive cuts over the watershed at Macacos (elevation, 47.24 meters), and descends again to the Capibaribe at Camaragibe (elevation, 35 meters). Upon inquiring the reason for this, I was told that the railway was not built through the gulch past Apipucos on account of the soft and spongy nature of the soil that fills the narrow valley.

A kilometer below São Lourenço there are terraces along both the banks of Rio Capibaribe at an elevation of about 10 meters above mean waterlevel. These terraces are visible for some 3 or 4 kilometers along the river. At many places the rocks are well exposed in the bed of this stream.

From São Lourenço upstream for several kilometers the rocks exposed in the stream bed are gneisses. At São Lourenço the gneiss is cut by a granite (or pegmatite) dike.

About 200 meters beyond the station at Tiúma the railway cuts gneiss that is decayed to a depth of nearly 20 meters. Here and there through the decayed mass are rounded (exfoliated) lumps of the unaltered rock. This cut is about 150 meters long. Near the top of the bank is a thin line of waterworn pebbles following the contour of the hills.

At Santa Rita, São Severiano, and Páo d'Alho the crystalline rocks are well exposed in the river bed. Below the bridge at Páo d'Alho the schists are decayed in place and exhibit the same bright colors as are found in the Tertiary sediments.

Beyond Páo d'Alho the slopes of the hills are gentler and the valleys broad, and the watersheds far away. On the hills between Páo d'Alho and Carpina (about 3 kilometers south of Carpina) the decayed crystalline rocks are covered by a layer of red clay, near the bottom of which is a layer of waterworn pebbles mingled with angular and subangular fragments of gneiss. In every observed instance these bands of pebbles follow the contour of the hills and are within 2 meters of the surface of the ground. In some places—not hilltops—the waterworn pebbles are 5 meters below the surface of the ground.

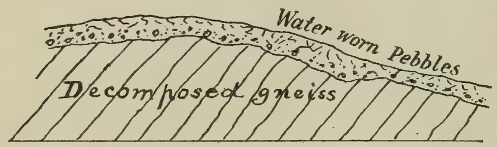


FIGURE 16.—*Section on the Railway between Pao d'Alho and Carpina.*

Carpina (kilometer 59.8), it will be observed, is the highest point on the road (182 meters), and is on the watershed between the Capibaribe and Rio Goyanna. Looking northward from Carpina the mountains on the horizon have a serrate outline; toward the northeast they are less broken, while to the southeast the skyline is even and horizontal. To the east of Carpina, about 3 kilometers, there is one high peak that overlooks the surrounding country.

Between Tracunhaem (kilometer 67.2) and Nazareth gneisses and some granites are exposed by the railway track, but there are no waterworn pebbles in the soil. At Nazareth station (kilometer 72.9) the gneiss is wrinkled and decayed. At the little station of Junco, between Nazareth and Lagoa Secca, the decayed rocks look more like schists than like gneisses. One of the cuts is about 20 meters deep, and the decayed rocks are mostly red. About 150 meters beyond the station of Lagoa Secca (kilometer 84.1) a cut exposes a narrow band of waterworn pebbles in the soil.

At Barauna station (kilometer 91.2; elevation, 73.6 meters) the rocks are schists. In the railway cuts 300 meters beyond the station the schists are deeply decomposed, and bands of waterworn pebbles pass through the thick clays and sands that overlie the rocks decayed in place. Two or 3 kilometers beyond the station these clays and sands are from 6 to

10 meters deep, where exposed in the cuts, and bands of cobbles, many of them 20 centimeters in diameter, run straight through the hills.

The pebble bands are derived from quartz veins that penetrate the schists along this part of the line.

At Aliança station again (kilometer 97.2; elevation, 59.2 meters) the rocks are decayed crystalline schists or gneiss with waterworn quartz pebbles overlying them in places. The schists here contain much mica.

From 300 to 500 meters beyond Aliança waterworn quartz pebbles 10 centimeters in diameter are exposed in the railway cut 7 or 8 meters above the stream level.

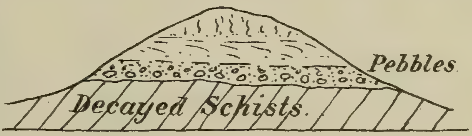


FIGURE 17.—*Section on the Railway near Barauna.*

At Pureza (kilometer 107.6; elevation, 70.2 meters) are decayed crystalline schists, and beyond the station the undecayed rocks are exposed in the bed of the stream. A kilometer beyond Pureza there are waterworn pebbles at the track level, and at Timbauba (kilometer 118; elevation, 100.7 meters) large waterworn quartz boulders are exposed near and west of the railway station. Some of these boulders are 20 centimeters in diameter, and are both subangular and well rounded. The rocks in place at Timbauba are either crystalline schists or gneisses.

The terminal station of the railway at Timbauba is on the watershed between the drainage of Rio Goyanna and that of the Rio Parahyba. The country around is hilly, but the slopes as a rule are gentle, and most of them are covered with cultivated fields to their very summits. There was not time to ascend the higher hills; as seen from the village, many of them appear to rise to an even skyline a hundred meters or more above the station, while above these rise several higher peaks. The accompanying sketch is made from a photograph taken near the Timbauba station.

So little is known of the nature of the waters of Brazil that I give here the analyses ordered made by this railway of waters taken at five different points along its line. These analyses were made for the purpose of determining the availability of the waters for use in locomotive boilers, but they contain information of much interest in regard to the amount of total solids in the waters, and they show something of the character of these constituents. These waters are from springs near the stations named in the table.

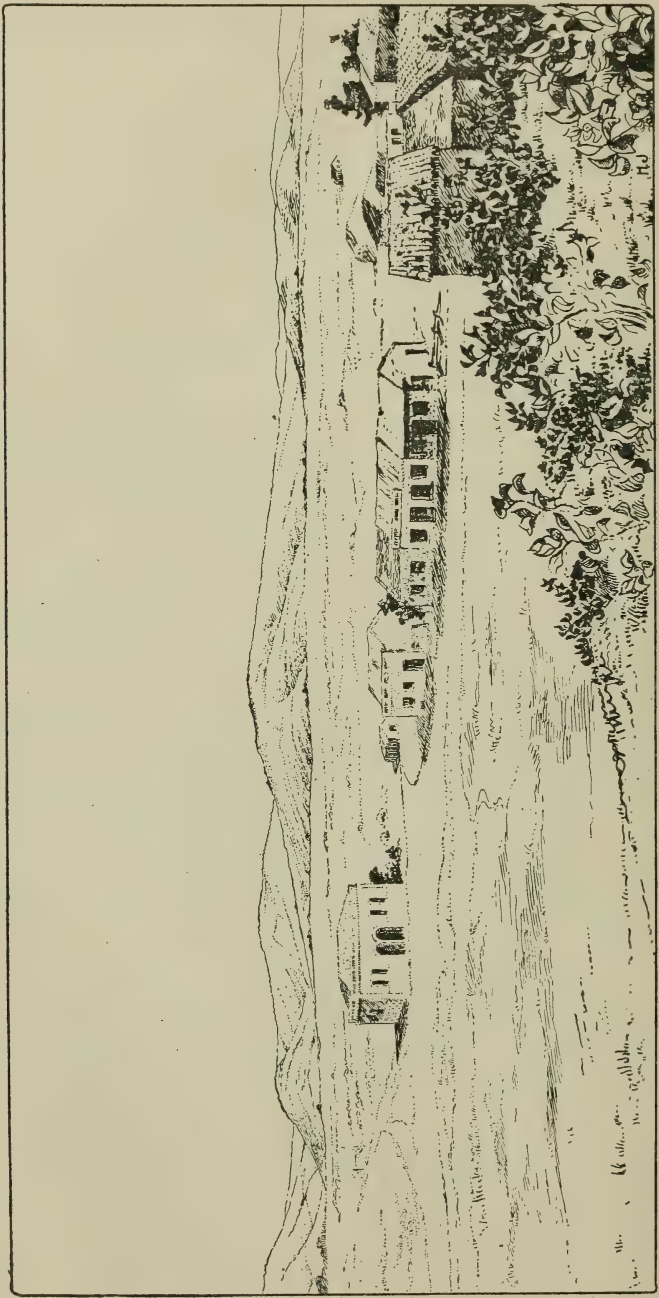


FIGURE 18.—*The hills west end southwest of Timbauba.*

*Partial Analyses of Waters along the Line of the Great Western of Brazil Railway (expressed in Grains per Gallon)**

	Timbauba, 118 kilometers, elevation 100 meters.	Pureza, 107 kilometers, elevation 70 meters.	Junco, 80 kilometers.	Nazareth, 73 kilometers, elevation 57 meters.	São Lourenço, 25 kilometers, elevation 31 meters.
Total solids	82.39	24.01	49.35	60.34	19.39
Lime	7.30	3.10	5.66	5.26	3.00
Magnesia	4.40	0.40	2.20	4.30	0.42
Chlorine	43.56	11.16	16.20	27.72	8.28
Total hardness	26.30	6.58	16.50	21.80	6.58
Permanent hardness	21.00	6.58	11.90	15.40	6.58
Degree of hardness	10.00	3.00	5.00	7.00	3.00

The facts of general interest shown by the geology along this railway line are here brought together.

CONCLUSIONS REGARDING THE GEOLOGY ALONG THE GREAT WESTERN RAILWAY

The particolored Tertiary beds forming the hills around the plain on which Pernambuco stands form only a narrow belt where they are cut across by the Great Western railway. These beds end a short distance beyond Macacos, so that the entire belt has here a width of only about 12 to 15 kilometers.

The Tertiary beds where exposed along the railway are without fossils, but what appear to be the same beds, where less weathered, as at Olinda, contain marine fossils, which are regarded by Professor Gilbert D. Harris, of Cornell University, as of Eocene-Tertiary age.†

The Tertiary sediments were laid down on an uneven surface of crystalline rocks—granites, gneisses, and schists.

The crystalline rocks are exposed from near Macacos to Timbauba, a distance of about 100 kilometers by the railway line.

Inland from the main Tertiary sediments waterworn materials cover the lower slopes of the hills, but these materials have not been observed at a higher elevation than a little more than 100 meters above tidelevel.

The marked colors characteristic of the Tertiary beds are sometimes found where the old crystalline schists, gneisses, et cetera, are decayed in place. It is therefore believed that some of the coloring of the Tertiary sediments is due to the weathering in place of the crystalline rocks, and that some of the Tertiary beds have therefore always been highly colored. In other instances the coloring has taken place subsequent to the deposition and elevation of the Tertiary beds. This is shown by the size and character of the particolored areas.

---

* For a copy of these analyses I am indebted to Mr John A. Lorimer, chief of locomotion on the railway.

† It is possible that there may be a thin bed of Cretaceous between the Tertiary and the schists and granites.

There is a notable topographic contrast between the region of Tertiary sediments and the region of old crystalline rocks. The soft Tertiary beds rise to an approximately even elevation and are cut by steep-sided, narrow, closely spaced valleys or gorges, while the region of old rocks is more rounded in outline and the valleys are broader and the elevated watersheds farther apart.

Geology along the Natal a Nova Cruz Railway

RAILROAD STATIONS AND TOPOGRAPHY ADJACENT THERETO

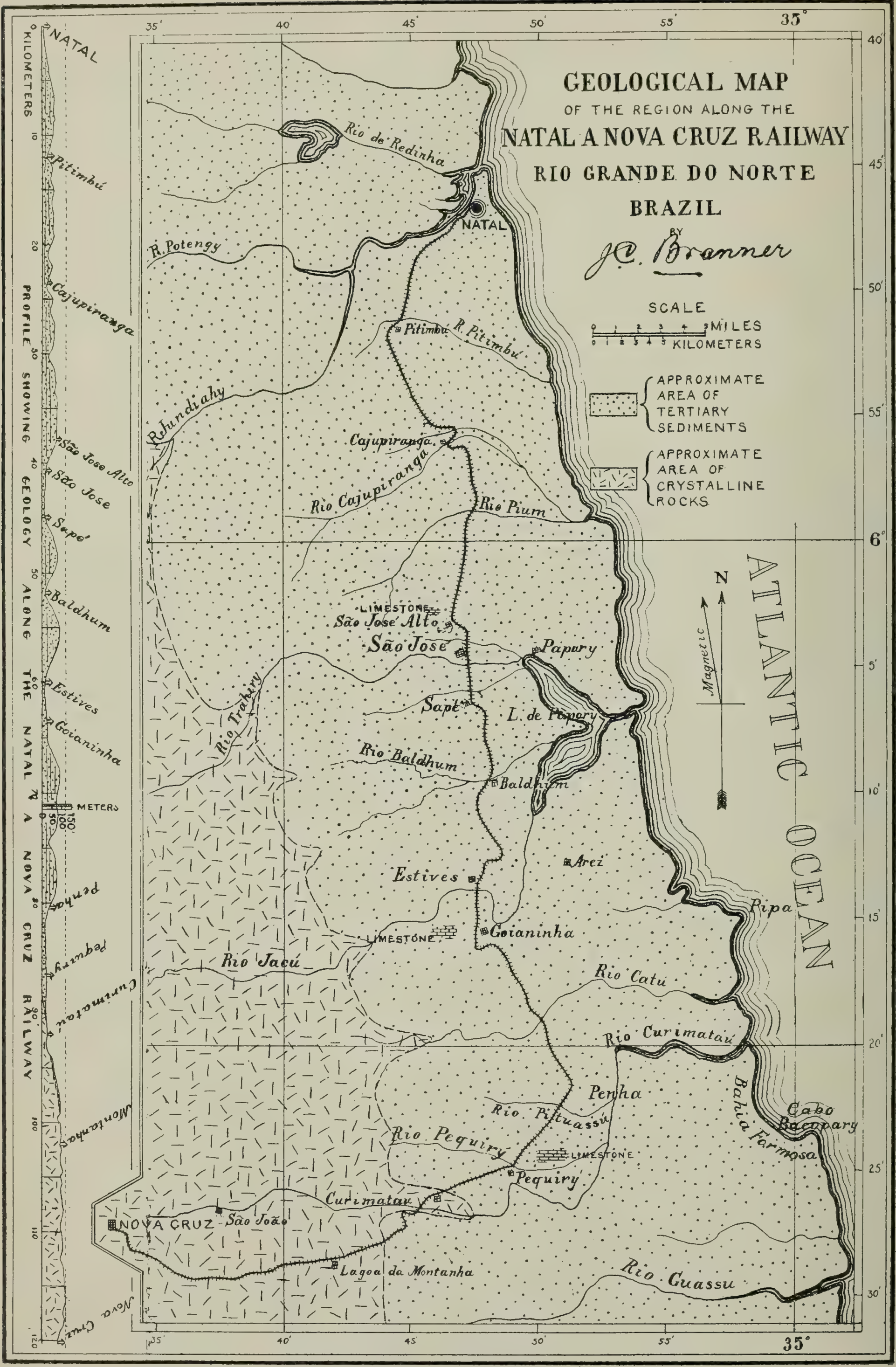
The lower part of the city of Natal stands on an alluvial flat, only a meter or two above high-tide level. This flat ends abruptly and sharply against the slope of the ridges, as if its materials had been deposited in water standing at that level against the hills. The " upper city " is on a hill of red Tertiary sediments that rises some twenty meters or more above high-tide level. The streams that cut across the region above or inland from the city are bordered by broad mangrove swamps, while the lowlands between the city and the sea is either mangrove or tide marsh or is covered with sand dunes.

At kilometer 3 the view over Rio Grande and the estuaries about Natal throw light upon the topographic history of the region. The water of the estuaries is bordered with mangrove swamps, and these swamps merge into flat lands which end abruptly against the rather steep slopes of the hills beyond. At kilometer 3 the railway is near the general level of the Tertiary plateau that forms the rather narrow belt along the Brazilian coast from Natal nearly to the mouth of the Rio São Francisco.

At Pitimbú (kilometer 12) the stream runs through a flat valley filled with a black, muck-like soil between steep hills.

From kilometer 15 to 19 the country is a somewhat rolling, but nearly flat, dry plateau, with a very scant vegetation.

The sand dunes that have blown up from the coast are visible from the railway at many places across the Tertiary plateau. Where the road approaches the coast they form a very striking feature of the topography—


GEOLOGICAL MAP
OF THE REGION ALONG THE
NATAL A NOVA CRUZ RAILWAY
RIO GRANDE DO NORTE
BRAZIL
BY
J C. Branner
SCALE
0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS
APPROXIMATE AREA OF TERTIARY SEDIMENTS
APPROXIMATE AREA OF CRYSTALLINE ROCKS
N
Magnetic
ATLANTIC OCEAN
PROFILE SHOWING GEOLOGY ALONG THE NATAL A NOVA CRUZ RAILWAY
KILOMETERS
METERS
150
100
50
Natal
Pitimbú
Cajupiranga
São Jose Alto
São Jose
Sapé
Baldhum
Estives
Goianinha
Penha
Pequiry
Curimatau
Montanha
Nova Cruz
NATAL
Rio de Redinha
R. Potengy
Rehundiahy
Pitimbú
R. Pitimbú
Cajupiranga
Rio Cajupiranga
Rio Pium
LIMESTONE
São José Alto
São Jose
Papary
Sapé
L. de Papary
Rio Trahiry
Rio Baldhum
Baldhum
Arez
Estives
LIMESTONE
Goianinha
Ripa
Rio Jacú
Rio Catu
Rio Curimatau
Penha
Bahia Formosa
Cabo Bacopary
Rio Pituassú
Rio Pequiry
LIMESTONE
Pequiry
Curimatau
NOVA CRUZ
São João
Lagoa da Montanha
Rio Guassu
35° 35′ 40′ 45′ 50′ 55′
6° 40′ 45′ 50′ 55′ 5′ 10′ 15′ 20′ 25′ 30′

GEOLOGICAL MAP OF THE REGION ALONG THE NATAL A NOVA CRUZ RAILWAY, RIO GRANDE DO NORTE long ridges of light brown or yellow sand, often more than 30 meters high and several kilometers in length.

Stations on the Natal a Nova Cruz Railway

Kilometers.	Station.	Elevation.
		Meters.
0.00	Natal	11
8.50	Divide	70
12.00	Pitimbú	26
17.75	Divide	62
23.50	Cajupiranga	21
30.30	Rio Pium	35
34.50	Divide	80
38.00	São José Alto	75
41.00	São José Baixo	21
41.20	Bottom of valley	14
45.00	Sapé	19
48.50	Divide	81
52.00	Baldhum	19
55.00	Divide	93
60.00	Esteves	18
63.50	Goyaninha	24
68.00	Divide	90
74.20	Catú valley	37
78.00	Divide	74
80.20	Penha	42
82.50	Bottom of valley	15
86.60	Pequiry	26
92.00	Curimataú	30
102.00	Lagoa da Montanha	93
115.50	Summit	125
120.20	Nova Cruz	84

Between kilometers 15 and 20 these dunes, seen in the distance, look like low mountain ranges. Just before reaching kilometer 21 the road cuts down along the Tertiary red hills, crosses a narrow valley, and ascends another Tertiary ridge, whose surface is strewn with many lumps and pebbles of iron.

Cajupiranga (kilometers 23, 24) is only 12 kilometers from the coast. It is situated in a flat fertile valley, about 0.2 kilometer wide, between Tertiary hills.

Another long, narrow, and winding valley, known as the Pium, is crossed by the railway at kilometer 30. It is only about 100 meters wide, but drains into the ocean.

São José Alto (kilometer 38) is one of the highest stations on the railway. Limestone is said to be quarried a short distance northwest of the São José station, but no specimens of the rock from these quarries have been seen. North of São José the plateau is flat. The country in sight is all Tertiary and is covered with a thin forest. The highest elevation reached by the railway on the divide between Cajupiranga and São José is 80 meters.

From the São José Parada one looks down on the Sapé valley—a wide and very flat valley with low hills here and there through it. Sapé station is on the east side of the low valley land. Through this valley flows the Trahirý river, but most of the valley, especially during the rainy season, is covered by a shallow freshwater lake or marsh 2 kilometers wide and known as Lagôa Mipibú. It is, however, a network of lakes and marshes rather than a single lake. It is said that the tides are not felt in this lake. At some places the topographic break between the valley floor and the hills is sharp and well defined; at others there is no great contrast, but the hill slopes and valley bottom merge gradually together.

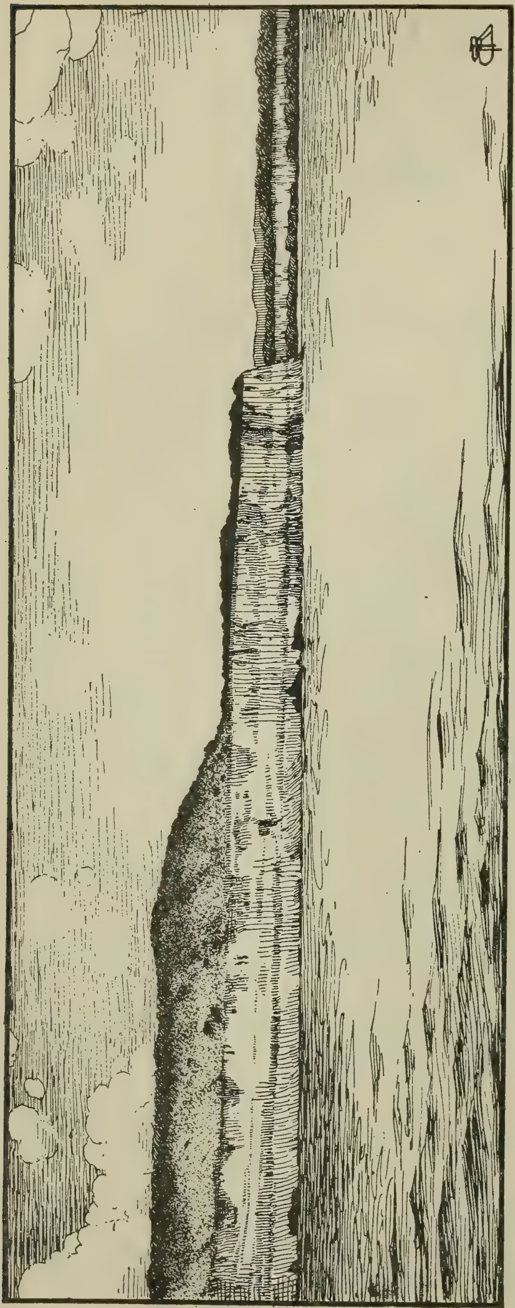


FIGURE 19.—*Ancient Sand Dunes Capping the Bluffs at Pipa.*

Northwest from Sapé the hills are Tertiary, and seen from the valley appear to be flat topped.

After passing Sapé the railway ascends the Tertiary hills of horizontal beds, and, passing the watershed, descends to Baldhum (kilometer 52), where there is a long, narrow, flat bottomed valley only about 100 meters wide.

South of Baldhum the railway ascends another red Tertiary ridge (kilometer 59), from which one looks out over the broad open Estevão valley. Descending to the valley, at kilometer 60 there is a small lake at Esteves station, and the railway crosses Rio Jacú, a small, sluggish, winding stream, with several small lakes along its course.

Goyaninha station, at kilometer 63.5, is in a flat valley about 5 kilometers in width. Limestone is said to be found west of Goyaninha, at the foot of the hills. It was not possible for the writer to visit the locality, but through the kindness of Mr Samuel H. Agnew, the superintendent of the railway, some small specimens of the rock have been received from the quarry at that place. The rock contains marine fossils, but the specimens received are small and the fossils so fragmentary that it is not possible to identify them. They consist of gasteropods and bivalve mollusks. The rock is a very sandy limestone, straw colored and streaked with brown and red.

From the Tertiary hills beyond (south of) Goyaninha one sees in the direction of the coast the sand hills that have been blown inland. Behind and landward of these hills in the valley is a great lake between Tertiary hills. These hills south of Goyaninha form a remarkably flat plateau or taboleiro, having an elevation of 90 meters, and is covered with a very sparse vegetation, chiefly *mangabeira* rubber trees.

At kilometer 75 the hills are still Tertiary (?). At kilometer 79 the road descends westward from the plateau-cutting Tertiary (?) beds here and there until Penha is reached on the Rio Pituassú. A little beyond Penha the railway enters a broad, flat, marshy valley and, turning westward, follows up it for several kilometers.

A few kilometers south of Penha station and north of Rio Curimataú there are several limestone quarries. It is said that lime is made half a league east of Pequirý station. Mr Agnew kindly sent me samples of the rock from one of the quarries south of Penha and east of Pequirý. The specimens received contain no fossils. They are all of a light gray color and on analysis prove to be dolomites.

Analysis of Limestone from near Penha

L. D. Mills, analyst.

	I.	II.
Lime (CaO),	29.08	29.05 per cent.
Magnesia (MgO)	20.10	19.92 per cent.

Inasmuch as limestones and dolomites are common in the Cretaceous beds farther south, and as no limestones have been found in the beds of known Tertiary age, it seems probable that these limestones may be Cretaceous.

Looking south from Curimataú station, the Tertiary (?) hills have the appearance of a flat-topped plateau. At Curimataú station the railway first comes upon the gneiss, which is here exposed by stream erosion in this deep, broad valley. These rocks in place are visible at the railway station and also at the bridge over the river.

After leaving Rio Curimataú the soil is pebbly for several kilometers; beyond this it is sandy. Then follow the Tertiary beds, and these are succeeded by crystalline rocks.

These crystalline rocks begin on the plateau about 5 kilometers beyond Rio Curimataú.

At Montanha station the rocks are granites and the land is gently rolling. Some quartzitic or cherty rocks seen at Natal on the cars are said to have come from kilometer 108, north of Montanha station. These rocks appear to be Paleozoic, but without farther examination or evidence nothing trustworthy can be said of their age.

About 1 kilometer north of Montanha, Tertiary (?) beds are visible. These are followed by granites, which are exposed here and there as exfoliated boulders and bosses. Farther on the Tertiary appears in patches again, and these in turn are followed by granites and gneisses, which continue to Nova Cruz (kilometer 121).

In the low grounds along watercourses and on some of the slopes the vegetation is thick and rank, but across the high flat Tertiary plateaus it is sparse, and in many places so much so that the ground is bare and hard and the landscape desert-like.

CONCLUSIONS REGARDING THE GEOLOGY OF RIO GRANDE DO NORTE

The facts of geologic interest in the section along the Natal a Nova Cruz railway are as follows:

1. The horizontal weathered Tertiary (?) beds common along the coast southward nearly to Rio de Janeiro form a belt from 15 to 25 kilometers wide through the region traversed by the Natal a Nova Cruz railway.

2. Marine fossils have lately been found in the beds near the base of the series west of Goyaninha, and they probably occur also in the limestones northwest of São José and south of Penha.

3. The fossiliferous limestones near Goyaninha are quite sandy.

4. Whether the upper beds exposed on the coast are the same as those yielding fossils inland is not known certainly.

5. The limestones south of Penha are, in part at least, dolomites, and lithologically resemble some of the Cretaceous limestones of the Sergipe basin.

6. These Tertiary (?) beds contain much iron, especially on the coast south of Natal, at and in the vicinity of Ponta da Pipa.

7. The Tertiary (?) beds thin out on the interior side, and their margin is a series of patches resting on the old crystalline series.

8. The sedimentary beds rest unconformably on crystalline schists and granites probably of Paleozoic age. These crystalline rocks cover the greater part of the interior of the state of Rio Grande do Norte.

9. The beds here spoken of as doubtful Tertiary may be Cretaceous at the base and Tertiary at the top; this is suggested by the geology of the adjacent state of Parahyba do Norte, as shown in the first part of this paper.

10. Weathering has affected the sedimentary beds along the coast in much the same way, whether those beds are of marine or freshwater origin.

11. Besides those mentioned at Goyahinna, one other occurrence of fossils has been reported in Rio Grande do Norte. In 1853 or 1854 Jacques Brunet, a French physician, while exploring the interior of Parahyba and Rio Grande do Norte, found fossil shells at Apody, on Rio Mossoró, in the northern part of the province.* Dr Burlamaque also reports limestone and chalk † sent from the same place by Brunet. The Apody beds are probably the Cretaceous (or Tertiary) limestone.‡

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*Noticia acerca dos animaes de raças extinctas descobertos em varios pontos do Brazil. Pelo Dr F. L. C. Burlamaque. Bibliotheca Guanabarense, Trabalhos da Soc. Vellosiana. 9 de Junho de 1885. Secção de Geologia, p. 19.

†Noticia acerca de alguns mineraes e rochas de varias provincias do Brazil, recebidos no Museu Nacional durante o anno de 1855. Por Dr F. L. C. Burlamaque. Revista Brazileira, Rio de Janeiro, 1858 (?), vol. ii, pp. 78–79.

‡Rocks containing Cretaceous fossils were reported to have been found by Dr Continho on Rio Mossoró in 1886. Contribuições a Paleontologia do Brazil por Charles A. White. Archivos do Museu Nacional do Rio de Janeiro, 1887, vol. vii, p. 10.

12. The most striking topographic features of the region traversed by the railway are:

The enormous sand dunes on the plateau southwest of Natal.

The flat bottoms of the valleys cut in the Tertiary (?) sediment, showing a comparatively recent depression of the coast.

In many instances these valleys are still in process of filling up. The great Mipibú lake is in one of these depressed valleys.

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 13, PP. 99-118 FEBRUARY 20, 1902

OUTLOOK OF THE GEOLOGIST IN AMERICA

ANNUAL ADDRESS BY THE PRESIDENT, CHARLES D. WALCOTT

(Read before the Society December 31, 1901)

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INTRODUCTION

A few years ago I outlined* what to me appeared to be the proper policy to be pursued by the United States Geological Survey. A kindly critic said of it: "There will not be much left for others to do if all that you have planned is carried out." Since that time the work of the Survey has progressed steadily along the lines then laid down, the only important exception being the study of the geology of public roads, which has been taken up by the Department of Agriculture; yet state surveys continue to flourish and expand, and any active, capable student or professor connected with school, college, or university may find more geologic problems close at hand than he can possibly investigate.

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* Popular Science Monthly for February, 1895.

I am often asked by young men, "What are the prospects for me if I take up geology as a profession? Is there work to be done and money to pay for it?" These questions have led me to make inquiries among active workers in American geology.*

THE PAST

GEOLOGIC WORK IN 1901

Method of treatment adopted.—Let us first note what has been done during the year just closed. It is impossible to characterize adequately the scope and quantity of this work without a larger draft on your time than I feel at liberty to make, but the examination of its units will show its great variety of theme and the breadth of its distribution. I shall attempt to include only what may be called profession work—the work of geologic surveys and museums, and of men whose researches are sustained, in whole or in part, by the funds of educational and other institutions. The labors of amateurs are by no means unworthy of mention; indeed, their contributions to geology are often of great importance; but the fact that their researches are usually private, becoming known only through publication, makes it impossible to list them for the year 1901 with any approach to completeness, and they have only indirect bearing on our primary question—the status and prospects of the professional geologist.

National organizations.—Foremost among the organizations and institutions which have sustained professional work are the national and state geologic surveys. The United States Geological Survey, including in its purview the whole country, gave continuous employment last year to thirty-six geologists and paleontologists, and availed itself temporarily of the services of about fifty geologists, paleontologists, and mining engineers. For the services and direct expenses of these officers and collaborators it expended the sum of $175,000. A still larger amount was devoted to accessory work of various kinds—chemical analyses of rocks, chemical and physical researches bearing on geologic problems, the making of topographic maps on which to delineate geologic boundaries, clerical and other aid connected with the indoor work and business management of the organization, and publication of reports and maps. The organization was also charged with the administration of investigations not regarded as auxiliary to geologic work, but rather as involving the practical application of geologic data, the chief of these being inquiries as to water supply, with reference to irrigation and other utilities, and the survey of the forest lands with reference to their protection and management.

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*In the preparation of this address I have received most valuable assistance from Mr G. K. Gilbert and Mr F. B. Weeks, and many geologists and paleontologists have furnished important data.

During the year 1901 the Geological Survey of Canada had thirty geologists in charge of parties or pursuing investigations independently of one another, in the field. Geologic reconnoissance surveys were made of several of the little known areas of the Dominion, and geologic studies of the occurrence of coal, copper, and the precious metals and other economic resources were prosecuted in the various districts.

The Instituto Geologico de Mexico engages the continuous services of a limited number of geologists. During 1901 its work comprised the preparation of monographs on the coalfields and on the rhyolites of Mexico. Studies of economic minerals, eruptive rocks, paleontologic material, and structural problems connected with the geologic section from Acapulco to Vera Cruz were also prosecuted.

State organizations.—The State of New York, in continuation of the great scientific survey which gave to American geology its stratigraphic and faunal standards, maintains a bureau for paleontologic work and another for geologic, and makes provision also for the preparation of a topographic map suitable for the refined delineation of geologic boundaries. New Jersey, which some years ago completed an excellent topographic map and has been wholly covered by geologic surveys, maintains a corps of geologists, whose function it is to carry on scientific and economic researches *pari passu* with economic development. Pennsylvania, which was the companion of New York in her great pioneer work and has since then conducted a comprehensive resurvey, now provides for a moderate amount of economic work and contributes to the production of a detailed topographic map. The geologic survey of Maryland, begun but a few years ago and comprising a comprehensive study of the geology and resources of the state, is being pushed to completion with unusual energy and rapidity. West Virginia has taken a new and vigorous start that promises well for the future. Moderate appropriations are annually made for the investigation of the geology and resources of North Carolina, Georgia, Alabama, Louisiana, and Texas. Ohio, having twice in the past instituted general investigations of her geology, now maintains a corps of experts, whose chief function it is to gather geologic and technical information in the interest of growing industries. She also makes annual provision toward the completion of an adequate topographic map. In Indiana a small amount of geologic work is supported by the State. Michigan, which has repeatedly called on the geologists for information as to her mineral wealth, now employs a permanent corps of geologists and mining engineers. Wisconsin, already in possession of comprehensive reports on her geologic features, makes annual provision for more refined and detailed study, both scientific and economic. In Minnesota the final results of a comprehensive survey are being elaborated and published. In Iowa a detailed areal survey is in progress, and there are also special investigations of geologic problems and mineral-using industries. Missouri, whose geologic survey has been retarded by many changes of policy and personnel, has recently placed her work in charge of one who commands our confidence as well as our good wishes. Kansas and South Dakota make moderate provisions for the prosecution of geologic research by the officers of their universities. In Colorado, Arizona, California, and Washington provision is made for a certain amount of investigation in connection with local mining industries.

Museums.—The United States National Museum provides laboratory facilities for paleontologists of the national survey and enables its curators in geology and paleontology to devote part of their time to original research. The Museum of Comparative Zoölogy, one of the institutions for research associated with Harvard University, carries on geologic and paleontologic investigations. The Peabody Museum, an institution of research associated with Yale University, is devoted chiefly to the collection and study of fossils and minerals. The American Museum of Natural History in New York, the Museum of Princeton University, and the Carnegie Museum in Pittsburg carry on important paleontologic researches, both in the field and in the laboratory.

Universities and colleges.—All of our larger universities and colleges, either directly or indirectly, give substantial aid to geologic investigations. In a few instances funds are contributed to defray research expenses in field and laboratory. In some cases the means of publication are provided. In all cases the teachers of geology are either permitted or expected to devote a portion of their time to scientific investigations. In a number of instances state surveys are by legal enactment associated with state universities, and the geologic survey of Maryland is conducted under the auspices of a university privately endowed. Prominent among the institutions which thus promote the progress of geologic science are Harvard and the Lawrence School, Yale and the Sheffield Scientific School, Columbia and the School of Mines, Cornell, Princeton, Lehigh, Johns Hopkins, Denison, Chicago, Stanford, Amherst, and the universities of Alabama, Ohio, Michigan, Wisconsin, Minnesota, Iowa, Kansas, and California; but the list might be extended so as to include practically almost every institution in which scientific instruction is so far differentiated that the subject of geology occupies the entire attention of one teacher.

Taking account of all these agencies, whether surveys, museums, or educational institutions, I estimate that seventy geologists are enabled by financial support to devote themselves wholly to professional research work; that fifty geologists, mining engineers, and technologists, though occupied chiefly in other ways, receive pay for special work in the field of research, and that seventy other geologists, employed and salaried as teachers, either are urged or are permitted without prejudice to devote part of their time to scientific investigations. The total would be carried above two hundred if to these were added those mining engineers who, gaining a livelihood by the industrial application of expert geologic knowledge, devote more or less of their leisure time to research.

Publications.—In this connection should be mentioned the important aid which geologists receive through various agencies of publication. While such aid does not contribute to the support of the student, it is sometimes the factor which turns the doubtful scale and makes a contribution to geologic science possible. The Bulletin of this Society, the American Geologist, and various scientific journals which give part of their space to papers on geologic subjects, are supported by the scientific men themselves, and from one point of view may seem to give no aid to the needy investigator; but it is really the readers who pay the printer, and the investigator is called on to pay only because he is also a reader. The Journal of Geology is not altogether dependent on its subscription list, but is practically endowed by the University of Chicago; and at New York, Baltimore, Granville, Lawrence, Berkeley, and Palo Alto the results of research are published in university transactions at university expense. The Wagner Institute devotes much of its income to paleontologic publications, and other institutions and societies, local and national, include geologists among the devotees of research to which the pages of their publications are open.

Of 21,600 printed pages on American geology in 1899, 12,000 were published by state and national surveys, 1,700 by geologic journals, 2,000 by other scientific journals, 500 by the Geological Society of America, and 5,400 by other associations and institutions.

Recurring now to the enumeration of investigations in progress during the last year, it will be convenient to begin with a geographic order.

Work in the various states.—In New Hampshire, Pirsson made field studies of the crystalline rocks, Hitchcock continued the investigation both of the structure of the older rocks and of the glacial geology in the vicinity of Hanover, and Dale continued the study and mapping of Paleozoic formations on both sides of lake Champlain. Metamorphic rocks in Worcester and Franklin counties, Massachusetts, were studied and mapped by Emerson, in southwestern Connecticut by Hobbs, and in central Connecticut by Gregory and Ford. Woodworth continued his studies of glacial phenomena and of Carboniferous strata in the Norfolk area, and Taylor studied and mapped the glaciated features of the Housatonic and Taconic districts.

In southwestern New York, Glenn made detailed studies of Devonian and Carboniferous strata with special reference to coal, oil, gas, and clays. In the Adirondacks, Kemp continued the mapping of crystalline rocks. Ogilvie mapped in detail the formations of a tract near Paradox lake, and Cushing of a tract north of Little Falls. Harris mapped the region above Crown Point and North Balcon island, on lake Champlain. Fairchild studied glacial deposits of the western part of the state, and Woodworth worked on the Pleistocene history of the Champlain-Hudson valley. Clarke conducted or supervised areal work about Canandaigua and Seneca lakes and the Niagara river and studies of the stratigraphy and life of the Rondout waterlimes, of the limestone lenses in the Rochester shales, and of the pyritic bed occupying the horizon of the Tully limestone west of Canandaigua. Beecher made collections of fossils from Devonian and Silurian horizons at Sheldrake, Hornellsville, and Rochester.

In Pennsylvania, Campbell and his assistants made detailed examinations of Carboniferous strata with special reference to the occurrence of coal, oil, and gas. Girty continued a study of the relations of the Lower Carboniferous strata and their faunas. Stose worked on areal and economic geology in the vicinity of Mercersburg and Chambersburg, and Bascom in the vicinity of Philadelphia. Williams studied the changing constitution of fossil faunas as traced westward from the central eastern counties.

In New Jersey, Ries continued the investigation of clay deposits; Kümmel and Weller studied Paleozoic formations at the northwest, and Woolman was occupied with the collection and correlation of data regarding artesian wells at the south. Wolff completed the study of a pseudo-leucite dike near Beemerville. Salisbury and Shattuck studied Pleistocene problems of the coastal plain region of New Jersey and Delaware.

Field work by the Geological Survey of Maryland included the mapping of Prince George, Harford, and Garrett counties, with local studies of clay and iron deposits; and laboratory studies of coal and fossils were prosecuted.

In West Virginia, I. C. White was engaged in the preparation of a report on the coals of the state.

Watson made a petrographic study of a part of the Piedmont plateau in Virginia and North Carolina.

Holmes studied the Columbia and Lafayette gravels and loams of North Carolina, tracing their equivalents in the Tennessee valley across the states of Georgia, Alabama, and Tennessee. Pratt made local studies of mineral deposits in the crystalline rocks of North Carolina west of the Blue Ridge, and was associated with Lewis in the study of the origin and relations of the corundum-bearing rocks of the western portion of the state. Keith revised earlier areal work in the Great Smoky mountains in North Carolina and Tennessee, and was otherwise occupied with areal surveys in Oconee, Pickens, Greenville, and Anderson counties, South Carolina.

Areal and economic work was continued by the State Survey of Alabama. Smith assembled and correlated the records of artesian wells in Alabama and Mississippi and made a local study in connection with borings for oil in Mobile county, Alabama. McCalley mapped a portion of the crystalline area in northern Alabama, and a portion of the Cahaba coalfield. Hall prosecuted a systematic investigation of the water powers of the state.

The gas wells of Louisiana, in Natchitoches, Winn, and Grant counties, were examined by Adams. Harris continued the study of underground waters, and Veatch worked on the geology of the Pliocene formations.

Ashley studied the Carboniferous strata of northern Kentucky and southern Indiana with special reference to the occurrence of coal.

In Ohio, Orton studied those resources which are likely to aid in the development of the Portland cement industry. Peppel investigated limestones with reference to their use for the manufacture of lime and lime mortars. Bownocker continued work on the oil and gas districts, and Lord on the fuel values, absolute and comparative, of the Ohio coals. Prosser studied the stratigraphy of Carboniferous, Devonian, and Silurian formations in various parts of the State and made a geologic map of the vicinity of Columbus.

Blatchley and Hopkins studied the partings between certain formations in the southern part of Indiana for the purpose of securing exact data for a geologic map, and Blatchley was further occupied with an investigation of mineral waters. Cummings made collections of Ordovician fossils.

In Michigan, Leverett and Taylor continued work on moraines and other features of the drift. Lane investigated the occurrence of coal in Saginaw county, and made studies also of underground temperatures and of the relations of formations penetrated by deep wells. Grabau continued a study of Devonian limestones. Davis investigated the origin of marls. Russell continued the investigation of the Portland cement industry of the state. Bayley continued work on structural and economic problems of the Menominee and Iron River districts. Gordon examined the oil and gas wells of the region about Port Huron, and McLouth studied the surface geology and oil wells about Muskegon.

In Wisconsin, Buckley continued the investigation of road materials and road construction, and Fenneman a physiographic survey of the lakes of the southern and eastern districts. Weidman made a study of the formations of Marathon and adjacent counties, and Hobbs of the pre-Cambrian volcanic rocks of the Fox River valley. Hobbs also completed his study of the pre-Cambrian volcanic rocks of the Fox River valley. Bayley continued work on the Florence iron district. Grant continued laboratory work on the geology and petrology of the Keweenawan rocks.

In Minnesota, Winchell was occupied with final publications of the state survey, and Van Hise and Clements continued the investigations of the Vermilion Lake iron district.

Calvin and his assistants, of the Iowa survey, continued the field investigation of clays and the collection of data as to artesian wells and the tracing of the boundary of the Iowa drift, besides carrying on areal work in Howard, Tama, Buena Vista, Cherokee, Monroe, Wapello, and Jefferson counties.

Buckley, after his appointment as state geologist of Missouri, began investigations of the quarrying industries, of materials for road construction, and of the lead and zinc deposits of the central district. In other lead and zinc districts the work of W. S. Tangier Smith was continued.

Adams made a field study of the relations of the Red Beds of Oklahoma to the Permian and Carboniferous series in Kansas. Taff made an areal survey of the Tahlequah and Salisaw districts, in Indian Territory, and a reconnoissance of Arbuckle mountain and the Wichita uplift.

In Kansas, Haworth made economic studies of petroleum, natural gas, and ores of lead and zinc, and Williston worked in the field and laboratory on vertebrate paleontology.

The Tertiary measures of Sioux county, Nebraska, were explored for vertebrate remains by a party from the Carnegie Museum.

In South Dakota, Darton and Todd continued the systematic and economic investigation of underground waters of Butte, Jerauld, and Sanborn counties, and Wieland and Granger searched for dinosaurian remains on the rim of the Black hills. Hovey worked on the geology of the Red Beds and Jura of the Black hills. Darton and Hall made areal surveys in North Dakota with special reference to the geology of artesian waters.

Weed continued detailed investigations of the Butte and Marysville districts of Montana. Willis, in a reconnoissance along the international boundary, examined the local structure and stratigraphy of the Rocky mountains. Winchell studied the problem of the age of the coal in the Great Falls region with special reference to its relation to that of the Little Belt region. Shaler worked on the general and structural geology of the Tobacco Root mountains.

Knight studied the Newcastle oilfield of Wyoming and made a detailed investigation of the Laramie quadrangle with special reference to underground waters. Adams studied water supply problems in Laramie and Converse counties. Two parties visited the state for the purpose of collecting vertebrate fossils, one operating at the north near Como lake, the other at the south in Albany county.

Cross continued areal work in southwestern Colorado; Emmons revisited the Leadville mining district and investigated recent developments, and Adams studied geologic structure in Weld county with reference to artesian problems. Matthew and Brown made a collection of vertebrate fossils in the eastern part of the state, and a party from the Carnegie Museum successfully exploited the Jurassic formations near Canyon.

In Texas, Phillips examined state lands west of the Pecos river with respect to their mineral value. Hill completed field work on the general geology of the Rio Grande region. The oilfields in the southeastern part of the state were studied by Phillips, Harris, Hayes, Adams, and Kennedy. Cragin continued laboratory studies on the Jurassic formations. Gridley made a successful search for remains of Pliocene horses.

In the southern part of New Mexico, Permian and Upper Carboniferous strata and faunas were studied by Girty.

Jaggar and Palache conducted an areal geologic survey and an investigation of mineral deposits in Yavapai county, Arizona. Lindgren made a geologic and economic survey of the Clifton-Morenci mining district, and Ransome of the Globe mining district. Blake made a reconnoissance of the vicinity of the Rincon Mountain region with reference to the possible presence of petroleum, investigated the lacustrine formations and diatomite deposits of San Pedro valley, and continued stratigraphic and structural studies in various mountain ranges. Walcott and Gilbert studied the Algonkian rocks of the Grand canyon of the Colorado.

In western Utah, Gilbert studied the stratigraphy and structure of mountain ranges and the physiographic expression of faults.

In connection with a reconnoissance survey of the international boundary, there was a study of the general geology of northern Idaho by Willis, and of northern Washington by Ransome and G. O. Smith.

Diller resumed the study of Crater lake, Oregon, and made a geologic reconnoissance in the Klamath mountains.

Becker made detailed studies of the Mother lode of California with special reference to the manner in which the gold was deposited. Lindgren continued the study of auriferous gravel channels of the Sierra Nevada and attacked also certain physiographic problems. Merriam began the systematic collection of fossils from the gravels, and traversed Mesozoic areas at the north for the collection of fossils. Branner made an areal geologic survey of coastal ranges in San Mateo, Santa Cruz, and Santa Clara counties. Diller made local surveys in Shasta county and the Honey Lake region. Eldridge investigated the distribution and conditions of the occurrence of petroleum, and Hershey studied the geology and physiography of the Klamath mountains.

In Alaska, Schrader studied the section along the 151st meridian from the Koyukuk river to the Arctic ocean. Mendenhall made a reconnoissance from the Koyukuk to Kotzebue sound via the Koyuk river. Collier was engaged in areal mapping in the northwestern part of Seward peninsula. Brooks was engaged in areal mapping and a study of the ore deposits of the Ketchikan mining district.

In Cuba, Hayes, Vaughan, and Spencer made a geologic reconnoissance with special reference to a study of the economic resources of the island.

Economic work.—In economic geology—that department of applied geology which pertains to minerals of recognized economic value—the year's work shows also a wide range. Geologic problems in relation to the occurrence of coal were studied in various parts of Pennsylvania, in western Maryland, in northern Kentucky and in North Dakota. The problems of petroleum and natural gas received attention in Pennsylvania, Ohio, Michigan, Kansas, Wyoming, Texas, Louisiana, Arkansas, and California. Problems of the precious metals were investigated in Colorado, Montana, California, and Arizona; of copper in Arizona, Michigan, and Wisconsin, and of lead and zinc in Kansas and Missouri. The geology of iron was studied in Wisconsin and Minnesota; the geology of artesian waters in New Jersey, Iowa, and North Dakota. Water resources for irrigation and power were investigated in the east from Maine to Alabama, in the central Mississippi River region, and in all the more westerly states and territories. Mineral waters received special attention in Indiana. Clays were studied from the economic standpoint in Maryland, Iowa, Tennessee, Mississippi, and New Jersey. The relation of clays and other rocks to the cement industry in Ohio and Michigan was investigated, and special investigations of materials available for road construction were made in Wisconsin and Missouri.

General researches.—Of more general researches, such as are not regularly classified by states, my list probably lacks much of completeness because many of them are not reported in the ordinary way.

Cross, Iddings, Pirsson, and Washington continued joint investigations bearing directly on the systematic classification of igneous rocks.

Van Hise continued a comprehensive study of the phenomena of metamorphism.

Merrill extended his studies of meteorites in their bearing on the problems of the earth's history. Much of the early work was crude and, in the light of today, unsatisfactory. With the refinements of modern chemical and petrographic methods, important results may be expected, and detailed work on the structure and composition of these interesting bodies is being carried on under the direction of the United States National Museum.

Lane is accumulating data on the grain of rocks as a function of position and composition, etcetera, and is extending his theoretical researches, especially of intrusives and of geothermal gradient.

Reid is engaged in the study of glaciers, their structure, stratification, movements, and the variations in size which they undergo. He is also engaged in the study of seismologic phenomena occurring in the vicinity of Baltimore, Maryland.

Shaler continued his studies of coast lines in general, with reference to recent changes in ocean level, and of the comparison of the lunar surface with that of the earth.

Gulliver continued the study of shoreline forms.

Davis completed a general study of the river terraces of New England.

Chamberlin was occupied with some of the broader and more fundamental problems of the science, including the mode of origin of the earth in connection with the development of the solar system; the origin and early constitution of the atmosphere and the ocean; the origin and early states of the earth's growth, which is entirely distinct from the early conception of meteoroidal aggregation; the mode of evolution of the oceanic basins and continental platforms; the original distribution and the secular change of distribution of internal heat and its function in the deformation of the earth; the autogenetic thermal conditions of the earth and their relation to early life, and the secular changes of land, sea, and atmosphere which constitute the basic features of historical geology.

Crosby completed a study of the Neponset Valley area of the Boston basin and investigated special problems in economic geology in various western states and in Canada.

Becker and Day carried forward two physical investigations bearing especially on metamorphism and the problems of the inner earth, the measurement of the linear force of crystallization, and the study of the general theory of elasticity.

PALEONTOLOGIC WORK IN 1901

Mention has already been made of purely local studies involving paleontology, but the greater part of paleontologic work is better adapted to stratigraphic or geologic classification than to geographic.

Dall's work pertained to the faunas of the Tertiary formation of Florida and the Tertiary formation and faunas of the Pacific coast between San Francisco and Crescent City.

Vaughan was occupied with studies of Tertiary faunas.

Knowlton began the investigation of Upper Cretaceous strata in southern Colorado and their fossil plants. He also collected and studied plant remains from Tertiary beds of California, Oregon, and Wyoming, and from the auriferous gravels of California.

Stanton continued a comprehensive work on the Lower Cretaceous faunas of the Texas region and began the study of the Cretaceous faunas of the Pacific coast.

Whitfield described new species from the Jurassic of South Dakota and Wyoming and from various other localities and horizons.

Wieland continued the monographic study of American fossil cycads.

Ward studied the geology of the Little Colorado valley in Arizona and continued the preparation of a second paper on the status of the Mesozoic floras of the United States.

Fontaine was engaged in studying Jurassic floras from Oregon, and also continued the study of the flora of the older Potomac formation.

Ward and Clark coöperated in the study of the Potomac terrane and its life.

White continued the stratigraphic and paleontologic study of data for the correlation of the lower terranes of the Coal Measures of the Appalachian region, and continued also a systematic work on the entire flora of the Coal Measures.

Weller studied the Kinderhook fauna of the Mississippi valley.

Girty worked on invertebrate fossils from Lower Carboniferous rocks in northern Pennsylvania and from Permian and Upper Carboniferous strata of southern New Mexico.

Williams continued his special work on Devonian faunas.

Clarke studied the origin of the invertebrate life of the Ithaca group, and made special investigation of the Guelph, Marcellus, and Hudson River faunas.

Beecher investigated Phyllocarida and Merostomata from Eodevonian strata.

Wortman continued the study and description of Eocene mammalia of the Marsh collection.

Osborn, besides continuing the preparation, study, and description of vertebrate fossils, gave much attention to the general correlation of American Tertiary and mammalian faunas with those of Europe. In conjunction with Matthew he also studied the American Tertiary faunas with reference to their geologic classification, and he was associated with Fraas in a study of the comparative age of American and European Jurassic vertebrate faunas.

Hyatt has nearly completed a monograph on the Pseudoceratites of the Cretaceous and a monograph on the Endoceratidæ and their allies. He has also prepared a table of formulæ representing the ontogenies of the principal types of ammonoids forming the genetic stock from which Lytoceras was derived.

J. P. Smith continued his work on the Triassic faunas of the Pacific coast.

Matthew was engaged in restudying the Cambrian areas and faunas in Cape Breton.

Hollick studied the later Tertiary floras of New Jersey and Maryland.

Walcott continued the preparation of a monograph on Cambrian brachiopods.

Scott was engaged in the exploration of portions of Patagonia and the collection of vertebrate remains.

Dean completed a memoir describing new types of placoderms and discussing the systematic position of the Mylostoma. He also began a study of the primitive sharks of the American Devonian.

GEOGRAPHIC SCOPE OF WORK IN 1901

The geographic range of the various studies in geology and paleontology was practically coextensive with the continent. In the United States the enumeration made has noted local studies in nearly every state and territory. The tracing of geologic boundaries or the mapping of formations was carried on in at least twenty-eight of these political divisions, or considerably more than half. Stratigraphic studies included the measurement and description of sedimentary series, and usually the collection of fossils pertaining to formations, of every geologic period. Collections of fossils for paleontologic study, and especially for the study of faunas, were made from every rock system from Algonkian to Recent.

How completely the field was occupied in petrography, dynamic geology, and geomorphology is not easy to say, because so large a share of progress on those lines is incidental. Most rock collections and much petrographic description and study are incidental to general geologic work, and the contributions to petrographic science which thus accrue find no place in current notices of work in progress, but only in final publications. Nevertheless, the ideas which make for the development of petrographic science are largely suggested in the course of such accessory and routine work, and, if it were possible to chronicle the year's progress in petrographic science, the increments made and recorded in connection with structural and areal geology would probably be found no less important than those made by the monographic study of series of rock specimens, and they would certainly have a wider range. The same is true in the whole range of dynamic geology. The students who go to the field or the laboratory for the purpose of solving specific problems as to the processes of terrestrial changes are comparatively few. The great body of workers in what may be called applied geology—the classification of local rock bodies according to existing categories, their description, and their delineation in maps and sections—these men are continually on the alert for phenomena which throw light on the many unexplained factors of geologic process, and it is mainly through their alertness that dynamic geology is advancing.

The Present

The outline which has been presented shows, approximately, the great variety of the geologic studies that are being prosecuted at the present time. A better conception of the extent and relations of these broadly outlined geologic studies would be afforded if it were practicable, in this connection, to state the problems which are known to geologists of the present day. But it is certain that even the briefest statement of known problems would extend this address far beyond its reasonable limit.

To illustrate: In a paper on the correlation of the Cambrian, published in 1891, was given an outline of the problems affecting our knowledge of the Cambrian series as a whole or in large part, and also many important local problems. It was recognized, however, that many of the local problems not given might, on investigation, be found to be of equal, if not greater, importance than many that were suggested. This brief outline of the Cambrian problems occupied 11 pages of printed matter. It will be readily seen that to extend such an outline to cover all the known problems of other time divisions would be an impracticable task at this time.

The larger problems of stratigraphy, correlation, oscillations between land and sea, the migrations of faunas, lines of descent, parallel development, etcetera, are all awaiting the student. The extent of the land areas and the variations in character, thickness, and distribution of the marginal and deep-sea deposits are imperfectly known. Structural and dynamic problems of the most far-reaching importance are awaiting solution. If the principle is accepted that the classification and delimitation of the divisions of the Paleozoic, Mesozoic, and Cenozoic eras must rest on the broad biologic characters of their included faunas and floras, and not on local breaks or differences of sedimentation, important problems remain as to where these lines of demarkation shall be drawn in most geologic provinces.

In studying the problems connected with the occurrence of ore deposits, the determination of their continuation in depth is of general interest. The terrestrial chemistry of ore deposits is one of the most important problems and requires investigation in many regions. The geologic conditions under which ores were originally deposited, whether they are all forms of concentration by aqueous solution or in part concentration from eruptive magmas, are subjects for continued study.

The field for research in physical geology is almost boundless, and so little has it been cultivated that the harvest will surely be abundant. Thus far geology has been pursued mainly by biologists, mineralogists, and stratigraphers. A few physicists have, indeed, applied their professional knowledge to the elucidation of the past and present condition of the earth and have reached results of first importance. Physicists, however, rarely have a sufficient acquaintance with geology to become deeply interested in the subject, while geologists seldom have a firm grasp of physics. A new school of geologists is needed, whose preparatory training should be mathematical and experimental physics, as that of a paleontologist is zoology.

Physical geology begins with the primeval nebula and the genesis of the earth-moon binary system. The causes of the heterogeneity of the earth's density evinced by the distribution of oceans and land masses and of the retardation of the earth's rotation and its effect on the arrangement of continental outlines are yet unknown. The thermodynamic problems of upheaval and subsidence, and the questions of deformation, of compression, of plastic solids and of rupture as affecting mechanics of orogeny, must be established. The effects of changes of climate in geologic time, the causes of glacial epochs, volcanic phenomena, the physics and chemistry of high temperatures, and many other problems of geologic physics have yet to be determined. The solution of these problems must fundamentally affect the science of geology.

In the early stages of American paleontology it was necessary that the fossils should be given names, and at the beginning of the present century we are more or less acquainted with many thousand forms. This great wealth of known forms will be very materially increased by future collections and studies; yet, with this great mass of material to be described, along with a reworking of many known forms, the paleontologist of the next decades will busy himself rather with the broad problems of stratigraphy, correlation, geographic distribution of fossils, relations of movements of uplift and subsidence, etcetera.

All our text-books refer to the historical formations as if they were so many clean-cut superposed time elements, but, speaking broadly, this indicates that we do not know the transition faunas. In these problems, and there are nearly as many as there are formations, local investigators will do their best work, since no great collections or libraries are necessary for the working out of local faunas. The fossils need to be collected in abundance, and the material from one zone and locality carefully kept together. The new species need to be carefully described and accurately figured and the type specimens deposited in one of the large central museums of paleontology, since in these centers of research the final sifting takes place. In this connection the large centers of research can cooperate with the local workers by advice, loan of material, and access to collections. In every geologic province a great field awaits the local institution, and no class of fossils can be neglected. One of the great omissions in paleontology has been the general neglect to gather the microscopic fossils like the Ostracoda, small Bryozoa, Foraminifera, and the young of Brachiopoda and Mollusca.

With the working out of the local faunas the solution of the intricate problems of time correlation will be possible, and we shall also be certain of the duration of species in time. With the species thus limited and restricted, lines of migration will become apparent, and in evolution our phylogenetic classification will have more certainty on account of the ascertained chronogenesis.

The investigations of the paleontologist have materially increased the subject-matter of the two biologic sciences, zoology and botany, and have anticipated them by many important histologic discoveries. The connection of paleontology with geology is even more intimate. Only by a study of their included faunas can the chronologic succession of clastic rocks be determined in many cases. In the main, paleontology is the ultimate foundation of historical geology.

The problems of structural geology may be said to be comprised in the relations of rock masses, the mechanics of movements involved in bringing the rocks from some original position into those which they now occupy, and the study of the effective forces.

New lines of theory to account for oceanic basins and continental plateaus, for thalassic deeps and mountain ranges, for rock folding, igneous intrusions, and vulcanism are opening before the student. From the conception of a heterogeneous earth comes the idea of isostasy, which, in its largest statement, is the theory that heavier masses beneath ocean basins are in balance with lighter masses under continents. The facts of folding are now understood to be of very superficial character considered relatively to the earth's radius, and any particular anticlinal or synclinal structure may be studied as a simple problem in mechanics involving certain materials, loads, and stresses. The sequence of sediments in any marine basin is the record of changing physical conditions along the shores and on the adjacent land. The development of a shore from youth to age, the growth of coastal plains, and the general topographic phases which passed on the adjacent lands are to be read in the rocks. Through such keys we shall decipher the history of the physical geography of the earth and the succession of mountain growths, and we shall approach the greater problem of continental growth.

Structural studies are now pursued with a better understanding of the mechanics of mountain growth, and through physiography and stratigraphy the history of deformation, past and present, may be made out. The science of structural geology may be said to be in its youth, with a future of great promise before it.

In the interaction between applied geology and pure geologic science lies the charm and the recompense of every-day routine geologic work. For the sake of future generalizations and for the sake of indicating the distribution of formations having economic value, the geologist performs a great deal of routine labor—observing phenomena of familiar kinds, grouping them in well known categories, and making a record for future use, chiefly by others. He describes rock masses, with measurements of thickness, extent, and dip. He sorts rock specimens, giving to the familiar familiar names and describing the characters of the novel. He sorts collections of fossils, recognizing species already known and describing such as are new. In performing these various duties he uses well established methods, and merely applies to new material the known principles of the science. Such work is necessarily monotonous, and the active mind would soon lose interest and its operation become perfunctory were it not for the possibility of discovering new principles. But ever and anon a fact is found for which the science has provided no pigeon-hole—a phenomenon which is not explained by any known principle—and thus a problem is presented which it is the delight of the investigator to attack. Geologic science, or the body of geologic principles, makes applied geology, or geologic art, possible, and reciprocally the practice of geologic art opens the way to progress in geologic science.

The Future

The preceding portions of the address have served to show the present condition of professional geologic work in the United States; that is, they give some suggestion of the quantity of work and indicate more fully its range in several respects. They show that geology, although affording occupation to a somewhat limited number of persons, is nevertheless a well established profession—a profession which flourishes in so many places and under such a variety of conditions that it may be assumed to have altogether passed the experimental stage. If its recent history were reviewed in connection with its present status, its development as a profession would be seen to have fully kept pace not only with population but with the general development of culture factors. There is no reason to doubt that its expansion will continue.

The areal work and other labors constituting the geologic survey of the country are but begun, and the task would require decades for its completion if no change were made either in the scope of the work or in the size of the working force; and this work is regarded as fundamental not only to scientific generalizations but to the intelligent guidance of economic enterprises. But experience warrants the prediction that the standards of the future will be progressively higher and higher, and that the scope of routine investigations will become broader. As geologic science progresses, and as new uses are discovered for mineral resources, it will become necessary to increase the number of classes of facts to be covered by areal surveys. In the field of pure science there is even less suggestion of the approaching completion of the work. Every investigation undertaken to solve some geologic problem, whether it prove successful or not, is sure to develop other problems, and the geologic Alexander will never lack worlds to conquer. This is a law of growth for every science and is merely an expression of the infinite complexity of nature.

It is impossible to forecast the problems of the future. When investigators are questioned they respond only with the problems of the present, but the problems of the present were equally unknown to an earlier generation. Suffice it to say that the work to be done in the field of geologic science is no less assured and no less important than the work in applied geology and in economic geology. Geology, as is so well stated by Sollas,* is in its evolutional stage, having passed through the catastrophic and uniformitarian phases of development. In becoming evolutional—

> " Not merely the earth's crust, but the whole of earth-knowledge is the subject of our research. To know all that can be known about our planet, this, and nothing less than this, is its aim and scope. From the morphological side geology inquires, not only into the existing form and structure of the earth, but also into the series of successive morphological states through which it has passed in a long and changeful development. Our science inquires also into the distribution of the earth in time and space. On the physiological side it studies the movements and activities of our planet; and, not content with all this, it extends its researches into ætiology and endeavors to arrive at a science of causation. In these pursuits geology calls all the other sciences to her aid. In our commonwealth there are no outlanders; if an eminent physicist enters our territory we do not begin at once to prepare for war, because the very fact of his undertaking a geological inquiry of itself confers upon him all the duties and privileges of citizenship. A physicist studying geology is by definition a geologist."

The question whether the geologist of the future can make his profession support him finds its answer equally in the interpretation of the history of the past. The support of the geologist depends on public appreciation of the value of his services. The growth of that appreciation is shown not only by the growing demand for researches in economic geology, but by the increasing willingness of legislatures and men of wealth to endow researches having for their immediate end only the acquisition of knowledge. It is more and more understood by men whose ability puts them in positions of responsibility that material progress depends, in the ultimate analysis, on the growth of knowledge, and from this increasing confidence in the ultimate utility of pure science research is reaping a generous harvest of endowment.

As we look back over the field of geologic work of the last century the retrospect may lead the young geologist to think that the great problems have been largely solved, that the future offers only the routine of areal work and local problems. That was my thought concerning the region east of the Mississippi in 1870, when reading the works of James Hall, the Rogers Brothers, Dana, and others. Once well into active work, however, I found that new and broad problems were opening up in the field I had chosen, the pre-Silurian sedimentary rocks, which I then thought to be limited as compared with those of the later geologic periods. Question after question, both local and continental, has come up for investigation. Most of them are still unsolved, and their study will bring a host of others that will line up before the mind of the student like the aisles of pines in the forests of the Sierras—some small and dwarfed, others strong and attractive, that are nearby, and farther away the less defined but silent mass that awaits his coming. We are only on the threshold of the golden era of geologic development in America.

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* W. J. Sollas, Evolutional Geology, Nature, vol. 62, 1900.

We older men are still endeavoring to do our part, but in a few years all the work will be turned over to the young men of today. Some persons here will look back from 1950 as we look back to 1850. There has been an advance since we began—20 to 40 years ago—and we have full faith that it will be sustained as generation after generation of geologists carry the grand work forward throughout the twentieth century.

In closing I wish to say a word about the training of the men who will probably reap the largest results from the great opportunities in geology that will be offered during the century. The practical economic geologist will undoubtedly receive the largest financial returns, but in this field the man with the broadest, most thorough training will win out as competition becomes more and more active. In the more purely scientific lines a broad, general culture should be the groundwork for the special geologic training. A few months of business training will be almost invaluable to any student who aspires to be more than a directed assistant throughout his career. Business method and habit must underlie all successful administrative work, whether it be of a small party or of a great survey. It is needless to say that, as in modern business life so in science, character of the highest standard is essential to permanent success. The outlook of the well balanced, well trained student in geology in America is most encouraging—far more so than when I began work with an honored leader, James Hall, a quarter of a century ago.

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
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GEOLOGICAL HORIZON OF THE KANAWHA BLACK FLINT

BY I. C. WHITE

(Read before the Society December 31, 1901)

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RESULTS OF ROGERS' INVESTIGATIONS

To one of the nestors of American geology, the immortal William B. Rogers, we owe the first description of the Kanawha black flint of West Virginia. In his "Fourth Annual Report of Progress" of the Geological Survey of Virginia for the year 1839 he gives such a full and minute description of this remarkable stratum that little has been added by any subsequent observer. He did not define its exact place in the stratigraphic column, but by making it the dividing line between what he called his "Upper and Lower Coal Series," there can be very little doubt that he correctly divined its proper horizon.

VALUE OF THE FLINT AS A KEY ROCK

Unique in physical aspect, easily discerned, and almost constantly present in the section, it constitutes a most valuable key rock in the greatly thickened deposits of the region. Hence with proper care on the part of the observer in keeping hold of the other members of the section below, as well as above this flint stratum, it readily leads to correct and accurate knowledge concerning the stratigraphic horizons of the principal Kanawha coal beds. For this reason it becomes a very important matter that such a conspicuous and valuable member of the Coal Measures should have its exact place in the geologic column determined beyond question.

Results of the first Investigations by the Writer

In 1884 the writer spent several months in the study of the Kanawha Coal Measures, collecting data for Bulletin No. 65 of the U. S. Geological Survey. In this work every stratum in the series from the Pittsburg coal near Charleston down to this black flint, as well as below it through the Pottsville series, was passed in review many times. As the result of this field study, the conclusion was reached that the Kanawha black flint marked a zone just above the Upper Freeport coal of the Allegheny formation, and I so published and described it in 1885 in volume VI of "The Virginias." This conclusion was deduced from purely stratigraphic evidence, based on a wide comparative study of the entire coal series of western Pennsylvania, northern West Virginia, eastern and southern Ohio, and the adjoining regions of Kentucky.

Investigations by Campbell and Mendenhall

In 1895 Messrs M. R. Campbell and W. C. Mendenhall, of the U. S. Geological Survey, undertook the task of classifying the Coal Measures on the New and Kanawha rivers. Their report was published in the Seventeenth Annual Report (part II, pages 479–511) of the U. S. Geological Survey. It contains many beautiful pictures, some observations on physiography, baselevels, and peneplains and some remarkable errors, but no detailed sections. Their net result in stratigraphy was to confirm in a general way what the writer had done ten years previously, and although dissenting from some of his identifications, they furnished no evidence against them. When they came to the problem of identifying and classifying the Kanawha series anew, they frankly gave it up in these words:

> "Stratigraphically they can not be accurately subdivided without an amount of detailed work altogether out of proportion to the value of the results obtained."*

The writer will agree that it required an immense amount of detailed work to solve the Kanawha problems, and this work he performed in 1884.

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*Page 499, lóc. cit.

Investigations by David White

After this complete surrender by Messrs Campbell and Mendenhall, they evidently turned the puzzle which proved too thorny for them over to Dr David White, the eminent palæobotanist of the National Museum and of the U. S. Geological Survey, who at the Washington meeting of our Society in 1899 read his paper, "Relative ages of the Kanawha and Allegheny series as indicated by the fossil plants,"* in which the problem of the black flint and of the Kanawha coals was attacked with the aid of palæobotany alone. His conclusions are in entire disagreement with mine. The stratigrapher and palæobotanist, each striving to discover the truth, have attained results diametrically opposed. David White places the black flint near the *base* of the Allegheny formation. The writer places it just above the *top* of the same. Hence the disagreement is vital, and one conclusion or the other is completely in error. It is a self-evident corollary that one or the other of us should revise his published statements, since it is not creditable to our science that its votaries attacking the same problem by two different paths should find themselves so widely apart in their conclusions that one of them has evidently missed the road entirely.

Concerning one of these warriors in behalf of science, I will gladly testify that he is brave, untiring, and honest, but in this case not sufficiently vigilant, since he was invading a new country characterized by exceptional conditions and environment (rapid subsidence and greatly thickened deposits), with which his old and trusty guides (fossil plants) were unfamiliar, and hence they piloted their general in the wrong direction—into confusion instead of order, into error instead of truth.

I do not call into question any of Dr David White's facts or plant identifications, for his skill and knowledge in palæobotany are beyond criticism, but only the interpretation of his facts in dealing with the problems of stratigraphy.

Recent Investigations by the Writer

METHOD EMPLOYED AND AREA COVERED

As already stated, my original conclusions concerning the place of the black flint were founded on the complete harmony of the stratigraphic column with the widely studied series in Pennsylvania, Ohio, Kentucky, and other portions of West Virginia, and not on the tracing of any particular coal bed or any other one member of the Allegheny formation across West Virginia from Pennsylvania to the Kanawha region. During the present year I have attacked the problem in question by direct tracing of the Upper Freeport coal and its associated strata from the Pennsylvania line along their eastern outcrops across to the Kanawha valley. In this I was entirely successful, and the result is a complete confirmation of my original conclusion with reference to the horizon of the Upper Freeport coal on the Great Kanawha, namely, that it is the first one below the black flint stratum, and hence this latter member belongs near the *base of the Conemaugh formation*, or just above the *top* of the Allegheny, where my studies in 1884 first placed it, instead of near the *base of the Allegheny*, to which position Dr David White has assigned it on the basis of fossil plants.

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*Published in Bulletin of the Geological Society of America, vol. xi, pages 145-178.

CHARACTERISTICS OF THE UPPER FREEPORT COAL

In this direct tracing the following elements enabled me to keep hold of the Upper Freeport coal:

First. The facies of the bed itself. It is always a multiple seam, with two or more divisions of slate or bone, the whole being characteristic to one who has learned to know a coal bed as one learns to recognize an individual from his physiognomy. This is an acquired faculty, and some people may reside on the Coal Measures all their lives and never attain it, just as some persons have difficulty in remembering human faces.

Second. The Mahoning sandstone series as a whole, which is easily followed from hill to hill in the topographic features it makes, even without recourse to its detailed lithologic structure, in which it possesses a peculiarity of its own very marked to the practiced eye.

Third. The Mahoning coal, a rather persistent member of the Conemaugh, occurring between the two members of the Mahoning sandstone at an interval above the Upper Freeport, varying from 40 to 80 feet.

Fourth. The Masontown coal, coming 10 to 20 feet above the top of the Upper Mahoning sandstone, its roof shales very rich in fossil animal remains at the north and in fossil plants at the south, and the coal itself always bright and pure, whether 1 foot or 4 feet in thickness, and nearly always present in the series at an interval of 120 to 200 feet above the Upper Freeport.

Fifth. A characteristic sandstone, 30 to 50 feet thick, overlying the Masontown coal and capping the highest summits along the outcrop of the Mahoning sandstone.

Sixth. The great "red bed horizon," which makes its appearance immediately above the sandstone group and extends in a bright red band, as plain as a chalk mark on the floor, clear across the state, as well as through Pennsylvania, Ohio, and Kentucky, thus making a complete circle of red deposits, occupying always the same relative position in the center of the Conemaugh, midway between two important coal beds, the Pittsburg and Upper Freeport. In this red shale belt there also occurs an important fossiliferous limestone horizon, the "green crinoidal limestone" of the Pennsylvania series, which has been traced from central West Virginia northward to the Pennsylvania line and through southwestern Pennsylvania into Ohio and across that state without a break to where it reënters West Virginia again at Huntington. In addition to this, the oil-drillers have traced this red horizon underground across the state, since it caves readily and gives them much trouble. They term it the "Big red cave," and never fail to find it at the proper geological level.

STRATIGRAPHIC RELATIONS OF THE FLINT

Hence with all of this evidence from stratigraphy, there can remain no doubt as to the place of this flint at the base of the Conemaugh, and that the Allegheny series of Pennsylvania and northern West Virginia must be found *below* it in the Kanawha region instead of *above*, as concluded by Dr David White from his study of the fossil plants.

Analysis of David White's Conclusions

In the paper referred to, David White concludes that most of the Kanawha coals below this black flint are older than the Allegheny coals and intermediate between them and the Pottsville series, and that hence my correlations of them with the several members of the Allegheny must be completely erroneous.

In order to sustain this conclusion Dr David White was compelled to find a place for the Allegheny coals somewhere, so he cut off the lower half of the Conemaugh and said, here they are. It is not my intention to deal with the question of the equivalency of the Allegheny and Kanawha coals in the present paper, since this whole subject will be treated in detail in my forthcoming report on the coals of West Virginia now in preparation, and to be published during 1902 as volume II of the West Virginia Geological Survey, but it is proper here to show the inherent improbability of David White's conclusions with reference to this branch of the subject.

He will agree with me that the Lower Carboniferous beds, the Greenbrier limestone, and Mauch Chunk red shale thicken from 800 feet at the northern line of the state to more than 2,500 feet on the Kanawha and New rivers; that the Pottsville conglomerate thickens from 450 feet to 1,400 feet in the same distance. He also agrees with me that the Allegheny series is 300 feet thick at the north, and that the Kanawha series is over 1,000 feet thick at the south. Why should the *expansion* of these sediments cease with the deposition of the Pottsville? Is it not more logical, aside from any evidence, to expect this thickening to affect the other formations above the Pottsville? In other words, that the 300 feet of Allegheny sediments and six coals at the north should merge into the 1,000 feet of similar sediments and the same number of coals at the southwest. Why should the analogy be interrupted and the Allegheny sediments *shrivel up* 150 feet when it is admitted that everything else below them has *expanded* more than threefold? Why should the Conemaugh decrease 200 feet in this direction instead of increasing by that amount, as my Charleston section shows on page 85 of Bulletin No. 65 of the United States Geological Survey? In this section there is given a measurement from the Pittsburg coal down to and including the black flint. This interval is practically a vertical measurement, since the Pittsburg coal is found in the summits of the hills only 2 miles north from Charleston, and the black flint passes below water level within the city limits. With due allowance for northward rise of the strata, the section foots up only 800 feet. The Conemaugh formation is seldom less than 600 feet in thickness at the northern line of the state, and frequently 650 to 700, and yet if we accept David White's correlation of the black flint as representing the Ferriferous limestone near the base of the Allegheny formation we are forced to believe that this 800 feet of strata at Charleston contains not only *all of the Conemaugh*, but also *nearly all of the Allegheny*, or, in other words, that in passing from the northern line of the state to the Kanawha, while the three other formations (Greenbrier, Mauch Chunk, Pottsville) have each *thickened up three or four fold*, and an intermediate formation (Kanawha) has *thickened* from 0 to 1,000 feet, the Conemaugh and Allegheny, which have a combined thickness of 900 to 1,000 feet even at the northern line of the state, have *shriveled up* to only 800 at Charleston. The mere statement of such a proposition is sufficient to raise very serious doubts of its truth, as well as to show the stratigraphic fallacies involved in Dr David White's conclusions from the standpoint of sedimentation alone.

But as my field studies on the question of tracing the coals below the Upper Freeport, southwestward from the Pennsylvania line to the Kanawha region, are not yet complete, I shall postpone the consideration of their equivalency in the two sections until another time.

The Masontown coal of the Conemaugh formation has proven a very persistent member. Although frequently only 18 to 24 inches thick, it retains its characteristics as a bright, clean coal, and will furnish much fuel in commercial quantity between the northern line of the state and the Great Kanawha river.

It is mined frequently in Preston, Barbour, and Upshur counties by the farmers, and is always preferred by them to the Upper Freeport below.

In the vicinity of Sutton, Braxton county, this coal has long been mined and has furnished the principal fuel supply for the town, although only 2½ feet thick.

Through Webster and Clay counties it appears to be universally present at the proper geological horizon, and frequent openings have been made on it by the farmers.

At Clay Court House it comes just above the great cliffs of Mahoning sandstone, at about 375 feet above Elk river, and is between 2 and 3 feet in thickness, though a few miles below, on the lands of Mr Thompson, it has thickened up to 40 inches.

At Queen Shoals, near the Clay-Kanawha county line, on Elk river, this coal is mined on a commercial scale and shipped by rail to western markets. It is so highly prized that orders for it cannot all be filled. It lies here about 175 feet above the black flint which in emerging from the bed of Elk river makes the "shoals."

The same coal is mined near Clendennin, and also at the Graham and Mason mines, in Kanawha county, and is the horizon from which Dr David White obtained the plants listed on pages 170, 171, etcetera, loc. cit.

At North Coalburg, on the Kanawha river, this coal is termed the "Big bed," and is extensively mined. Its interval there is 175 feet above the black flint by accurate measurement, according to the levels of Mr C. C. Lewis, of Charleston, West Virginia.

This Masontown Coal horizon is unquestionably in the Conemaugh formation, entirely above the Mahoning Sandstone group, and yet on pages 172–173, loc. cit., its flora is referred by Dr David White to the Kittanning horizon, while the flora of the same coal at Clay Court House is referred to the Freeport group. It is needless to say that such results discredit the use of fossil plants for refined stratigraphical determinations, and must continue so to do until the coal flora and its geographical diversity are more completely known.

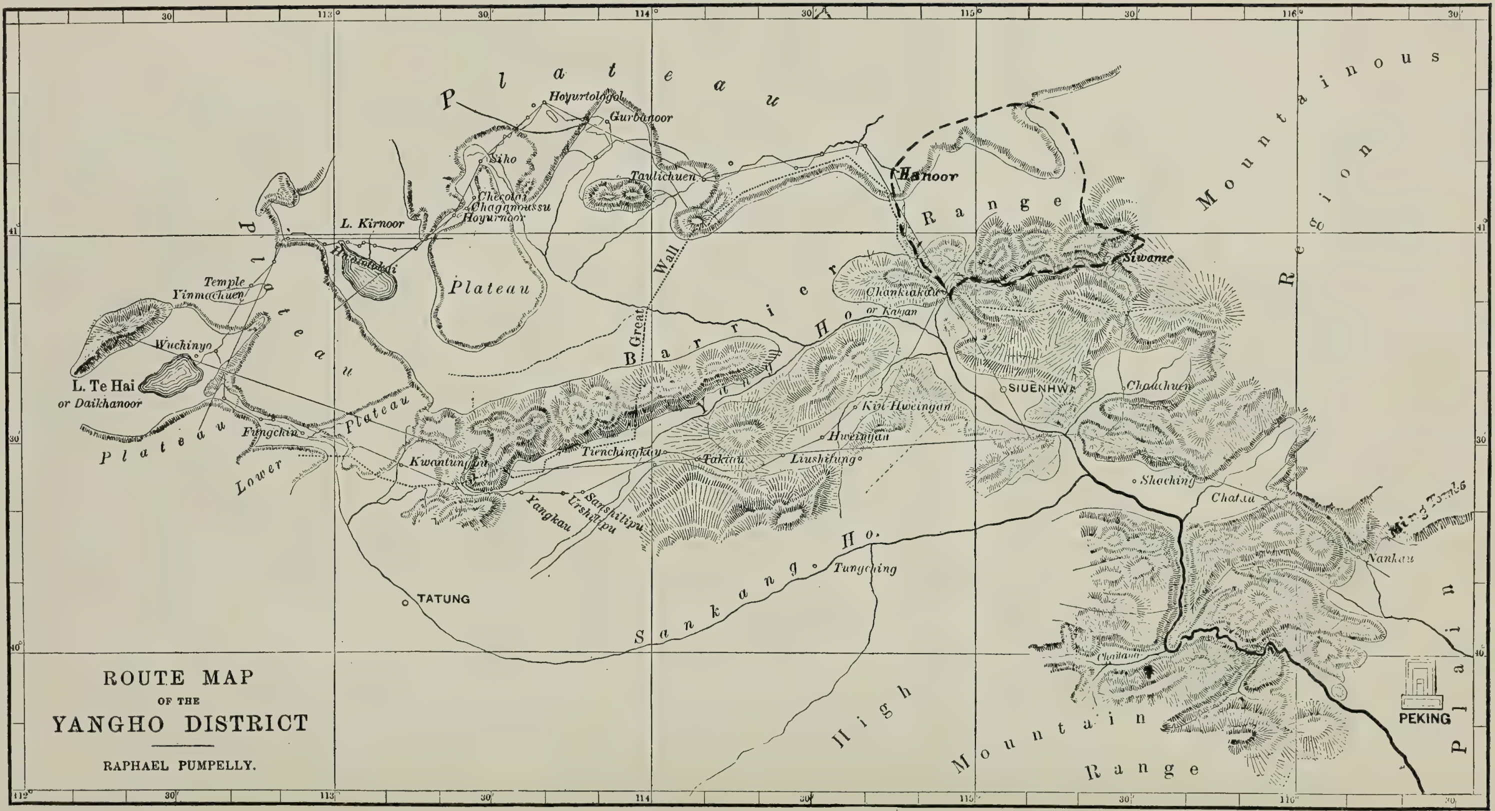
Stratigraphic Corollaries

In concluding this discussion the following important corollaries should be noted by every geologist interested in problems of stratigraphy:

1. Some individual coal beds, limestones, and sandstones can be followed and identified for hundreds of miles, in the Appalachian basin at least, and hence the doctrine that no coal bed can be certainly identified by stratigraphic methods beyond the limits of a small, circumscribed area is both erroneous and mischievous, leading to confusion and useless duplication in nomenclature instead of to order and simplicity.

2. When stratigraphy and palæobotany disagree, the latter must yield, since the few fossil plants we know can be only a tithe of those which must have existed, and hence we cannot reason with absolute safety upon such incomplete data.

3. Until we can know the Coal Measure flora more fully, and can work out its geographic distribution with more accuracy than is now possible, it must prove an uncertain and misleading guide to the correlation of distinct coal seams and horizons when widely separated, unless checked and controlled by stratigraphy. In other words, owing to the imperfection of our knowledge, palæobotany should be used only as an aid in supplementing the work of stratigraphy when we come to the detailed identification of individual coal seams or even groups of these beds.


ROUTE MAP
OF THE
YANGHO DISTRICT
RAPHAEL PUMPELLY.
Plateau
Hoyurtologol
Gurbanoor
Siho
Taulichuen
Checolai
Chagannussu
Hoyurnoor
L. Kirnoor
Plateau
Temple
Yinmachuen
Wuchinyo
L. Te Hai
or Daikhanoor
Fungchin
Plateau
Lower
Plateau
Great Wall
Barrier
Hanoor
Range
Siwanze
Chankiakau
or Kalgan
Ho
SIUENHWA
Kin Hweingan
Hweingan
Liushifung
Tienchingkau
Takiau
Kwantungpu
Sanshilipu
Urshilipu
Yangkau
TATUNG
Sankang Ho.
Tungching
High Mountain Range
Chauchuen
Shaching
Chatau
Ming Tombs
Nankau
Chaitang
PEKING
Plain
Mountainous Region
113°
114°
115°
116°
30′
41°
40°
112°

PORTION OF NORTHERN CHINA TRAVERSED BETWEEN PEKING AND MONGOLIAN BORDER

(Altered from Pumpelly)

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
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ORIGIN AND DISTRIBUTION OF THE LOESS IN NORTHERN CHINA AND CENTRAL ASIA

BY G. FREDERICK WRIGHT

(*Read before the Society January 1, 1902.*)

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INTRODUCTION

In the third edition of Professor Geikie's "Great Ice Age," published in 1894, he expresses the opinion, on page 699, that the materials of the loess in Asia "are largely of fluvio-glacial origin, and represent in great measure the flood loams swept down from the mountains and plateaus when they supported vast snow fields and glaciers;" and, in accordance with this theory, extensive areas in eastern Mongolia, in Transbaikalia, and in central Turkestan are marked on his glacial map of Asia as having been covered with ice during the Glacial period. My recent trip across Asia, in company with Frederick B. Wright, was largely directed by the desire to obtain more definite evidence on this point than could be found in any published reports. We accordingly went to Peking, and from there traveled on muleback 150 miles directly west to Kalgan, thus crossing a typical portion of the loess-covered area in northern China. From Kalgan, which lies at the base of the eastern mountain border of the Mongolian plateau, which is here about 5,000 feet above the sea, we ascended, along the line of the caravan route, to the summit at Hanoor, from which point we struck off northward, following the edge of the plateau for a distance of 30 or 40 miles, where we turned eastward, and after crossing two successive mountain ranges came out at Shiwantse, and thence returned to Kalgan, and from there by a somewhat different route to Peking, making in all a journey of about 450 miles. The portion of it from Kalgan around the Mongolian border to our starting point took us over a region where the glaciers, to account for the loess of China, must have existed, if the loess were indeed of glacial origin. The object of this paper can best be accomplished by a somewhat detailed statement of the observations made on the most typical localities in this part of our journey.

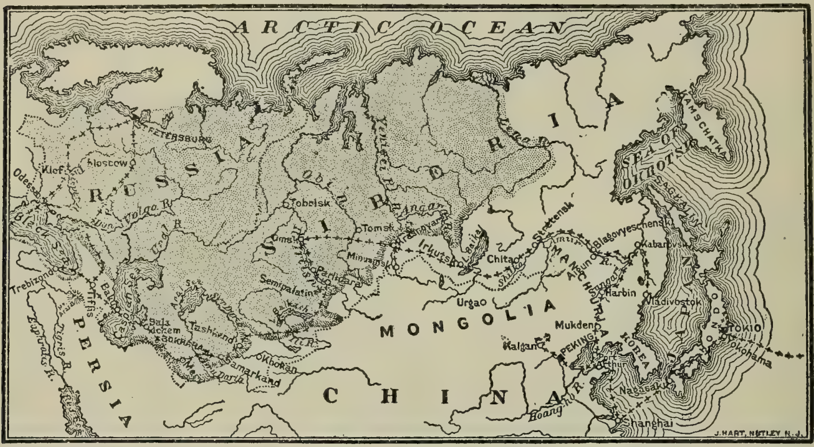

ARCTIC OCEAN
SIBERIA
RUSSIA
PERSIA
MONGOLIA
CHINA
KOREA
SEA OF OKHOTSK
KAMSCHATKA
Petersburg
Moscow
Kief
Odessa
Tobolsk
Tomsk
Omsk
Irkutsk
Chita
Semipalatinsk
Urgao
Mukden
Kalgan
Peking
Harbin
Vladivostok
Khabarovsk
Tokio
Yokohama
Nagasaki
Shanghai
Tashkend
Samarkand
Trebizond
Tiflis
Tigris R.
Obi R.
Volga R.
Amur R.
Hoang
J. HART, NUTLEY N. J.

FIGURE 1.—*Route traveled*

Shaded portion indicates the approximate area in northeastern Asia supposed to have been recently submerged

But, as preliminary to this detailed statement, it will be profitable to present in brief a few general facts bearing on the subject.

PRESENT ACTIVITY OF EROSIVE AGENCIES

All the rivers of northern China are densely loaded with sediment derived from the loess-covered areas through which they pass in the upper portion of their courses. In this respect they much resemble the Missouri. The vast plain of the Hoangho, in northeastern China, consists essentially of this sediment, which has been deposited gradually by the river. The river in the lower part of its course now occupies a channel raised considerably above the great mass of the plain, which stretches away on either side. It is owing to this position of the river that periodical floods so often devastate the interior, and that the mouth of the Hoangho is subject to such variation. The river now empties into the gulf of Pechili, about 150 miles south of Tientsin, but not long ago it wandered over the southern plain and joined the Yangtsekiang 150 miles above Shanghai, 400 miles south of its present outlet. On the other hand, at the present time, during extreme floods, portions of the water turn off to the north, near Kaifun, and, after a course of 350 miles, join the Peiho at Tientsin. Indeed, this most fertile portion of the Chinese Empire is a broad delta of modified loess deposited by the Hoangho, its base extending from Tientsin to Shanghai, a distance of 600 miles, and its apex having a breadth of about 300 miles.

A general impression of the rapidity with which the denudation of the loess is proceeding may be formed by noticing the extent of dense muddy water which borders the whole Chinese shore of the Yellow sea. When 40 miles out from Shanghai, the traveler encounters a sharply cut line, which can be distinctly seen for a long distance in either direction, separating the clear water of the ocean from the turbid, opaque, silt-laden water brought down by the great Chinese rivers. It is thus evident that deposition of loess is now taking place with great rapidity all along the Chinese side of the Yellow sea.

This is further shown by the extensive shoals and sand banks which extend from Shanghai nearly to the Shantung peninsula. They mark an extension of the combined delta of the Hoangho and of the Yangtsekiang, as the former has from time to time turned its flood in that direction; but the historical record of the growth of land on the gulf of Pechili is still more convincing of the activity of this transporting influence. Pao-to, on the Peiho river, was near the shore 200 B. C. It is now 40 miles inland. As late as 500 A. D. the sea was 18 miles nearer Tientsin than it is at the present time, while the increasing difficulty experienced by ships in approaching the harbor of Taku, at the mouth of the Peiho, is confirmatory evidence of the rapidity of this sedimentation. The records show that all along the shore of the gulf of Pechili the land for the last 2,000 years has been gaining on the sea at the rate of about 100 feet per annum. These facts need to be borne in mind when considering the date of the period of the accumulation of the loess over the interior region penetrated by these Chinese rivers.

Loess on the Border of the Plain of Peking

Peking is situated near the northeastern extremity of that broad belt of modified loess stretching out on either side from the Hoangho which we have been describing, and is about 30 miles from the base of the bordering mountains, which limit the plain on the northwest, and about 80 miles inland from the sea. From near the border of the mountains to the sea through Peking the slope of the surface is pretty uniform, averaging about 6 feet to the mile, so that the surface of the loess at the entrance to the pass at Nankau is about 600 feet above tide. The slope from Peking to Nankau, however, is considerably greater than it is on the other side toward the sea. Issuing from the pass at Nankau, a very distinct delta extends out on the plain for a distance of between 5 and 6 miles. This delta consists of a rather confused intermingling of loess with sand and gravel and occasional fragments of rock a foot or two in diameter. This coarser material occurs near the surface as much as 4 miles outside the mouth of the gorge, the surface sloping to that distance in a direct line at the rate of 50 feet a mile, making 200 feet in the first 4 miles; but on the southwest side the descent is abrupt, leaving a long low plain several miles wide between the delta and the mountains in that direction.

On the contrary, on the northeastern side the deposits of loess, at nearly the same level with the head of the delta, stretch for many miles along the base of the mountains toward the Ming tombs. In many places here we passed between perpendicular sections of loess 15 to 20 feet in height. They were especially prominent in the vicinity of a small stream coming down from the mountains about half way between Nankau pass and the Ming tombs, a distance of about 10 miles; but the larger stream coming down from the mountains into the amphitheater around which the Ming tombs are built has worn a broad deep channel in the sedimentary deposits, and occupies a bed 50 or more feet below the general level. This bed is thickly strewn with boulders several miles away from the base of the mountain. The portion of one of these boulders projecting out of the ground measured 9 by 6 by 3 feet.

From the situation of these deposits, it would seem pretty clear that they sustain a definite relation to the comparatively small streams coming down into the plain from the mountains to the northwest. Of these the Bishaho, which comes through Nankau pass, is the largest. But it seems difficult to resist the conclusion that at the time of the deposit of the deltas waterlevel was met at the base of the mountains at the elevation of 600 feet, which is that of the head of the delta spreading out from the Nankau pass. It seems also clear that at the time of the main deposition the material to which the stream had access was much more abundant than it is now, for at the present time all these streams are rapidly eroding material at these higher levels and transporting it to lower levels. The Bishaho, having completely abandoned the line of its old delta, now

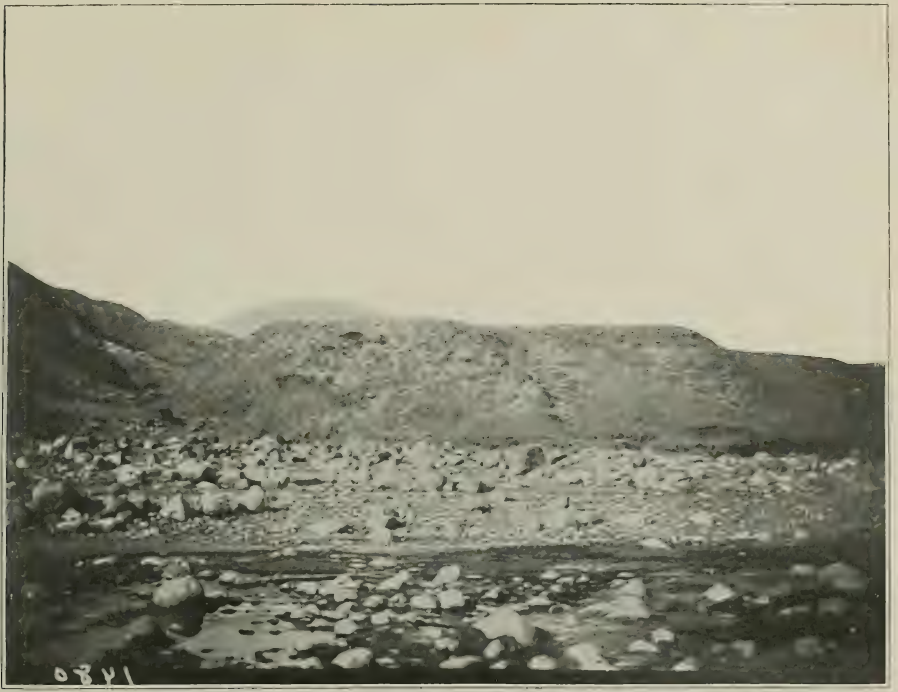


FIGURE 1.—SOUTH SIDE OF LOESS DELTA, NANKAU PASS, CHINA

Loess contains many stones and beds of gravel

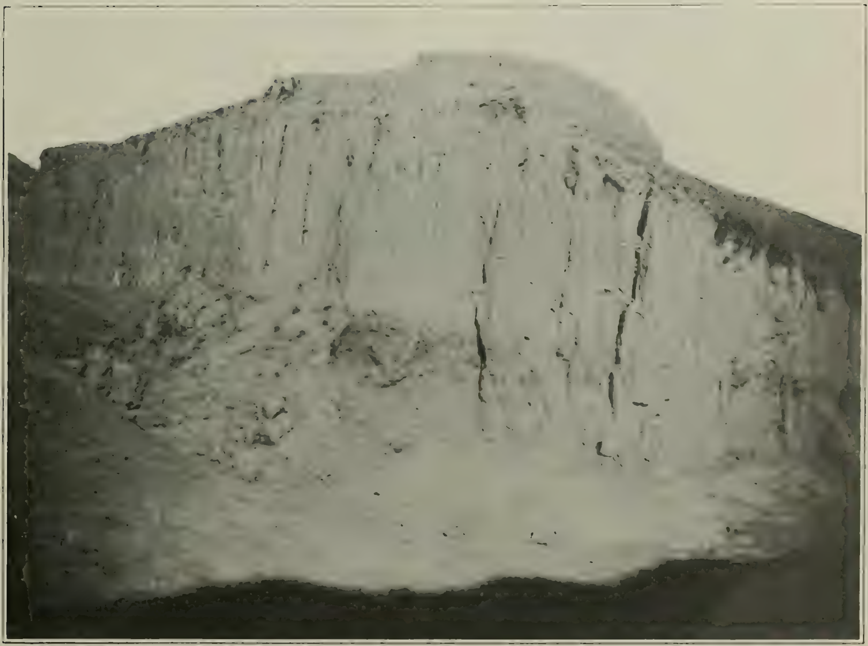


FIGURE 2.—LOESS BLUFF NEAR KALGAN

It is about forty feet high and contains pockets of gravel

LOESS DELTA AND LOESS BLUFF

turns off to the south, to meander along the low plain intervening between it and the mountains in that direction, at a level 200 feet lower than its former bed.

Loess west of the first Mountain Range

On crossing the first low range of mountains, which in this vicinity are nowhere more than 3,000 feet in height, but rise south of the Hunho to a height of 6,000 or 7,000 feet, we come into a valley from 15 to 20 miles in width and extending 60 or 70 miles in an east-and-west direction, through which tributaries of the Hunho reach the main river on either side from opposite directions. At an elevation of 40 or 50 feet above the flood-plain of the northern tributary numerous fresh-water shells are found, indicating an expansion of still water over a considerable area. For a distance of 30 miles from Huilasen to Chiming the road follows near the base of the mountains which border the west side of this plain. No streams of any great length come down from that direction, but all of them, short as they are, are marked in front of their mouths by extensive fans or cones of dejection, there being much coarse material in the direct axes of these cones, or deltas as they might be called, shading off into deep deposits of loess on either side, so that the road leads regularly across deep deposits of loess which often stand in walls with perpendicular faces from 20 to 30 feet in height along the road, alternating with lines of coarse gravel and river pebbles standing at somewhat higher level. Here, again, it would seem difficult to explain the extension of these delta-like deposits into the plain, except on the theory that the material was originally brought by the streams into a body of standing water, which determined the order of the deposition. Certainly, at the present time the loess is undergoing rapid erosion and is everywhere being rapidly swept down to lower levels.

Loess west of the second Mountain Range

From Chiming the road leads up the Hunho river through a remarkable gorge which penetrates the second range of mountains, leading after a few miles into another broad valley which stretches out its arms in a northeast and southwest direction between the low mountain chain and the parallel border of the Mongolian plateau. This is imperfectly drained by the upper tributaries of the Yangho, one of the main branches of the Hunho. This is not, however, a continuous plain, since the surface is often broken by rocky protuberances of considerable extent. There is, however, a pretty well marked border of the plateau all along the western side, next to the Mongolian escarpment, consisting for the most part of basaltic rocks belonging to a comparatively recent (probably Tertiary) eruption. For a great extent all over this region the loess has accumulated in level areas, which resemble lake basins. In many cases these are without outlet, and contain remnants of larger bodies of water, which are now drying up, leaving well marked terraces at elevations of considerable height around the rim. In many of these level areas of loess within the drainage basin of the Yangho there are numerous deep narrow ravines, with branching tributaries, cut to a depth of 100 feet or more by retrograding erosion, the loess standing in perpendicular faces on either side. Pumpelly describes one of these chasms as "more than 75 feet deep, with a width of only 4 feet between vertical walls of loam, and winding in a crooked course for more than a mile." In many places, especially near the bordering ledges of rock and near the center of the larger valleys occupied by the main stream, there are distinct lines of coarse gravel and rocky fragments interstratified with the loess. This oftentimes continues for a long distance over a comparatively level area, where it would seem impossible for superficial currents from local cloudbursts to have produced the results.

On the other hand, it was noticed that in the narrower valleys running east from Kalgan to Shiwantse, between the lofty border of the Mongolian plateau and the nearest border range, there were numerous and extensive deposits of loess that had been very clearly drifted in by the wind. The resemblance of these deposits to immense snowdrifts accumulating on the lee side of the mountains was very striking. This was especially the case at Shiwantse, where the entire village of 1,500 or 2,000 inhabitants finds shelter in commodious and comfortable houses dug into the hillside of loess which flanks the eastern face of the mountain range. These houses are excavated in successive receding stories one above the other, the natural roof of one house serving as the front yard of the house above it. These dwellings extend for 300 feet or more up the slope of the loess, which continues upward for a considerably greater distance. In this valley we saw many such villages, and in crossing the mountain from west to east found extensive drifts of the loess up to a height of 5,000 feet above the sea. But the greater accumulations of loess were below a level of 3,000 or 3,500 feet above the sea, and in many cases, even on the margins of the larger and deeper valleys, were spread out in such extensive and level areas as to suggest a terrace deposit near the margin of standing water. It became increasingly difficult for su to believe that wind could have distributed the material with such an even surface on the margin of such well marked and deep valleys as we repeatedly crossed.

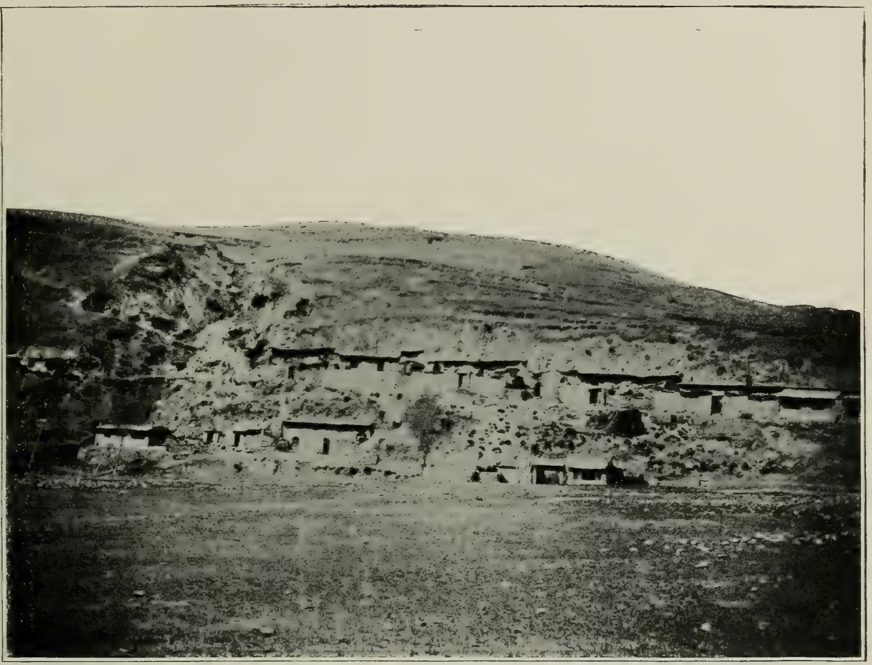


FIGURE 1.—EASTERN FACE OF MOUNTAIN AT SHIWANTSE

Showing homes in the loess, and also erosion effects

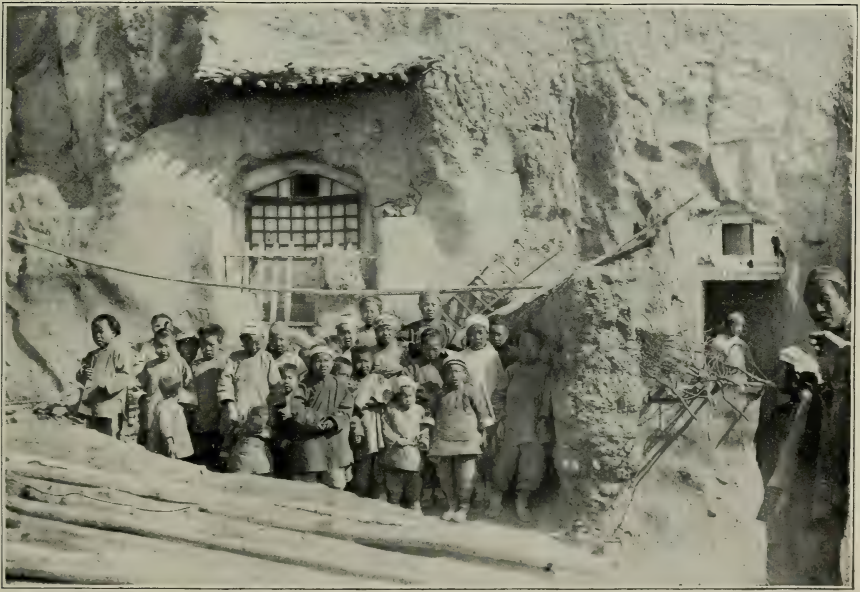


FIGURE 2.—HOUSE EXCAVATED IN LOESS AT SHIWANTSE

HOUSES IN AND EROSIONS OF LOESS AT SHIWANTSE

In one of these valleys, near the Mongolian escarpment, there was especially clear evidence of the recent cessation of the agencies which had been distributing the loess in its normal quantities. This was 2 miles above Hanchinbah, in the first stream east of the escarpment, running southwest between mountain ranges about 2,000 feet higher than the valley. Here is a bluff of loess about 40 feet in height, and extending back from the stream in a well defined terrace for a considerable distance, yet it was exposed to the direct force of the stream in a concave bend with its unprotected perpendicular face to the stream. The stream bore every mark of being at times torrential, its bed being full of large boulders, some from 4 to 5 feet in diameter, all in slow process of transportation down the stream. The gradient of the stream here was between 100 and 200 feet per mile. That so large an expanse of loess should have been accumulated to such an extent by present agencies, or should have remained in this unprotected position for many thousand years, would seem improbable, not to say impossible.

Gravel Banks near Hanoor

On the road from Kalgan to the summit of the Mongolian escarpment at Hanoor, there is an immense accumulation of gravel near the base of the escarpment, about 2,000 feet below the summit and about 3,000 feet above the sea. This has been well described by Pumpelly and its puzzling character fully recognized by him. The road extends through it for 2 or 3 miles, the gravel banks rising on either side to a height of from 100 to 200 feet. On ascending the banks, the surface is found to be nearly level, though having been subjected to considerable erosion. On the southwest side, the outer Chinese wall follows the summit of the gravel for a considerable distance as it climbs upward toward the escarpment. On the northeast side the deposit has a breadth of 2 or 3 miles, appearing, according to Pumpelly, on one of the parallel roads coming down to Kalgan from the plateau. When first encountering this gravel, we felt confident that it was an overwash deposit from a glacier which had covered the interior, and temporarily, when melting, poured its torrents down from the face of the escarpment; but on reaching the plateau and traveling many miles along its border, there were no signs that ice had ever covered the region. For a considerable distance to the interior, the border of the plateau here consists of a basaltic overflow which has obscured everything underneath, and the slope begins almost immediately to be directed toward the interior, nor are there any signs of even temporary lines of drainage across the escarpment to the east, such as might have been produced by glacial ice obstructing the natural western drainage lines.

It is possible that this remarkable gravel deposit, which certainly covers several square miles, is the delta of some old drainage line from the interior which has been covered by the basaltic flow now extending all along the edge of the border; but it is more readily explained as a shoreline deposit of recent age when the water stood at that level. What lends some color to this hypothesis is that the accumulation projects from what would have been the apex of a broad promontory extending into the sea where cross-currents coming down from the valleys on the northeast and the northwest would be likely to meet.

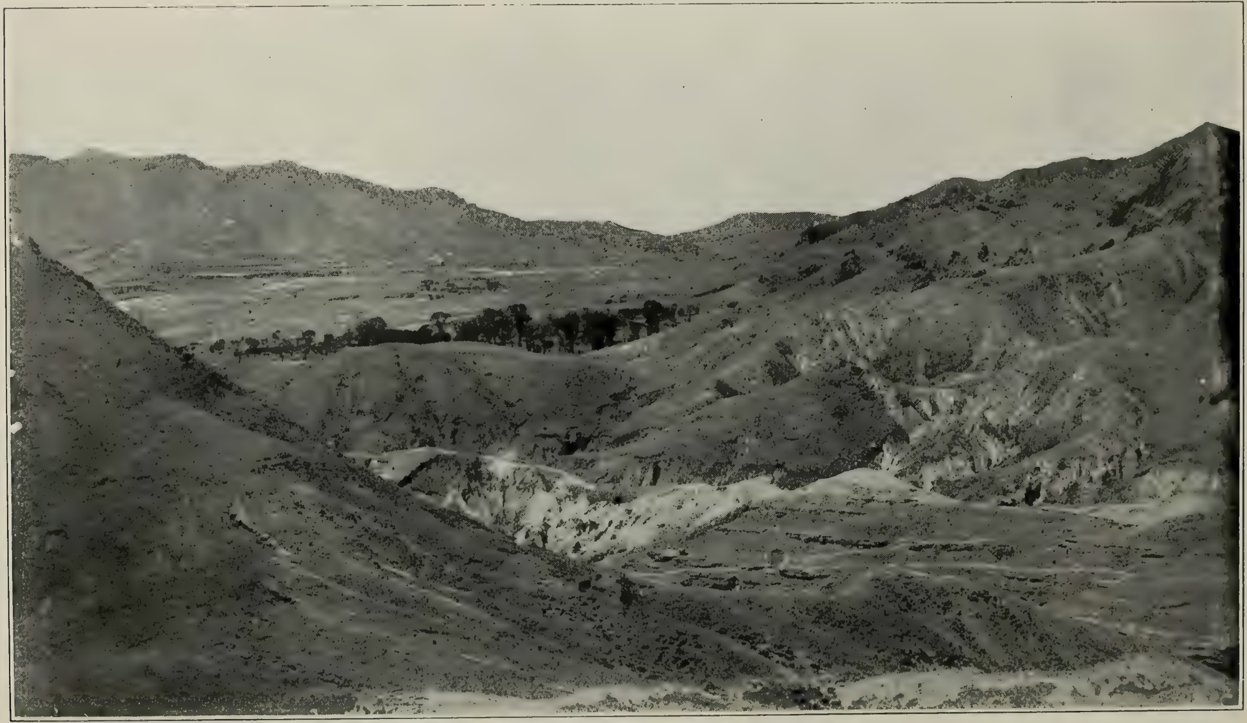
Absence of glacial Evidence in Region northwest of Kalgan

But, whatever theory is entertained as to the distribution of the loess and gravel at these elevations, its glacial origin can not be maintained, since there is a marked absence of all signs of glaciation over the area from which the material must have come. This we ascertained not only by an extensive detour into the mountainous region to the northwest of Kalgan, extending over the watershed of the Mongolian border, but subsequently by one of 2,000 or 3,000 miles through the center of Manchuria across the Little Kinghan mountains and the Vitim plateau to the south end of lake Baikal. Here, if anywhere in eastern Asia, we had been led to look for clear evidences of extensive glacial action, but it does not exist, and no extensive glaciers ever covered that portion of the Asiatic continent which could by any stretch of the imagination be supposed to furnish the material for the loess in northwestern China. We must therefore look to some other source for its origin.

Wind and Water combined as distributing Agencies

The source of the loess is probably to be found, as Richtofen pointed out, in the desiccated area of central Mongolia now occupied by the desert of Gobi. Here during long ages the superficial rocks have been slowly disintegrating under the conditions of an exceedingly dry climate, accompanied with great alternations of heat and cold, while the wind has been constantly transporting it in clouds of dust toward the eastern and northeastern borders, where it has been detained in excessive quantity in the moister climate of the mountain valleys lying east of the Mongolian escarpment.

But it seems necessary, from the facts presented, to believe that its present distribution over northwestern China was mainly secured by the agency of gradually receding water, the presence of which would be obtained by a temporary general depression of the land about 3,000 feet.



LOESS PLAIN BORDERING DEEP RAVINE WEST OF SHIWANTSE

Thus only can the main accumulations into extensive plains filling the depressions between the mountain chains, with all their anomalies of apparent terraces and interpolated beds of gravel and fragments of rock, be accounted for. So limited is the subsequent erosion that this period of depression must be brought down to some such moderately recent date as that to which we are now compelled to assign the Glacial period.

In confirmation of this theory as applied to eastern China, it is in place to point to the indubitable evidence of the recent existence of an inland sea as large as the Mediterranean over the area of the desert of Gobi, and connecting, probably, through the Sungarian depression between the Thian Shan and the Altai mountains, with a vast submerged area in western Turkestan and Siberia. The existence of this internal sea of central Asia is attested by the abundant sedimentary deposits about its margin which have been studied, especially in the vicinity of Kashgar, and also by the Chinese historical references to it as the "Great Han Hai," or Interior sea.

Confirmatory Facts from Turkestan

Instead of following the Trans-Siberian railroad to its western terminus, we left it at Omsk, and, turning up the Irtysh river, traversed by tarantass the belt of country extending from Semipalatinsk to Tashkent, a distance of 1,200 miles, along the northwestern base of the great mountain system of central Asia. Here pretty uniformly, at an elevation from 2,000 to 3,000 feet above the sea, we found that the remarkably fertile belt, along which Mongolian hordes have marched from century to century in their westward migrations and expeditions for military conquest, consist of broad expanses of loess very different from the desert sands of the north. This also is spread out in such terrace-like extensions from the base of the mountain as irresistibly to suggest deposition along the margin of a standing body of water; but there were no signs that glaciers had ever extended out upon the plain. Here, too, the indications that they were accumulated in their present position during a comparatively brief epoch, and that they had not been subjected to present erosive agencies for an indefinite period, is of the same character as that adduced for northwestern China.

Other Evidences of recent geological Changes in the Region

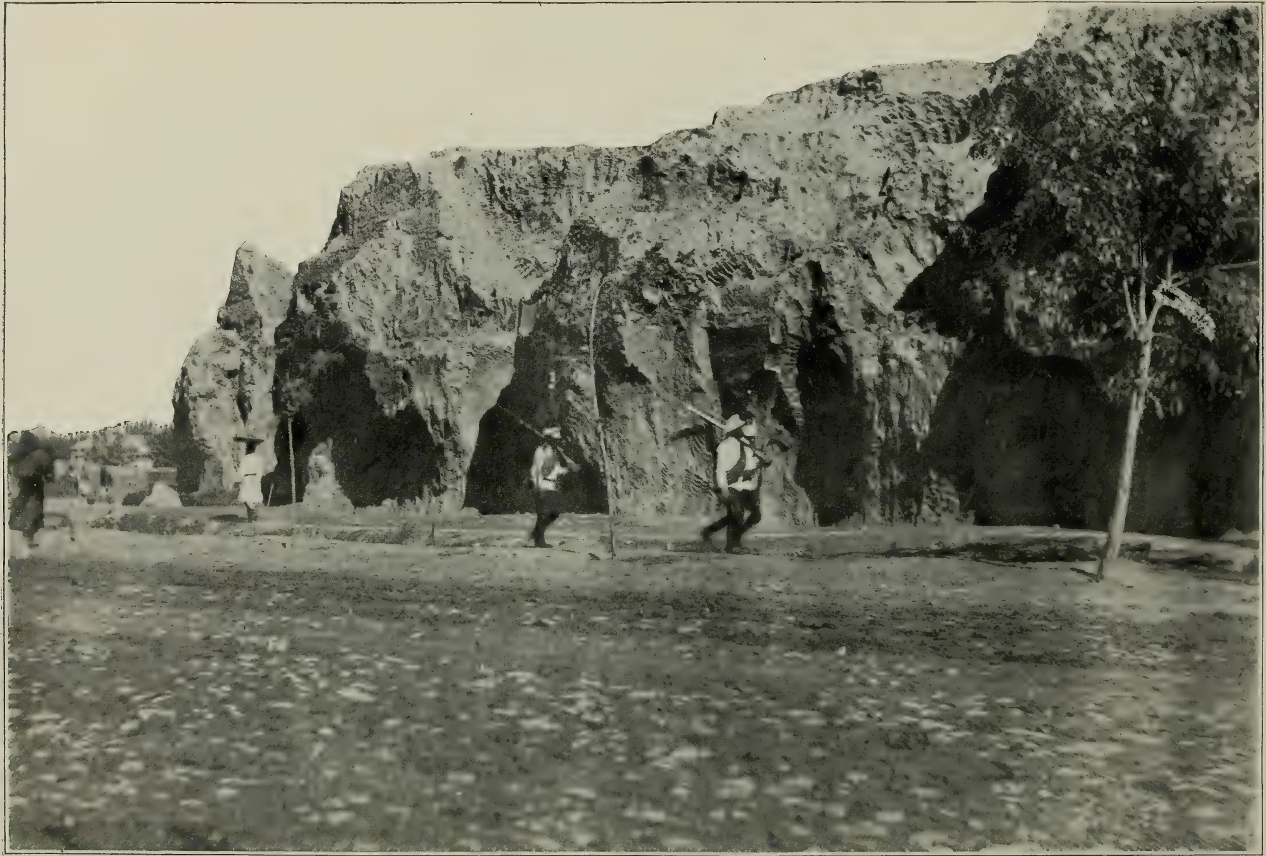
In confirmation of this theory of a short continental subsidence of central Asia in post-Tertiary times we may point to the general evidences of recent extensive changes of level throughout the region, indicating an instability of the earth's crust extending down to a comparatively recent time.

1. As is well known, the Himalaya, Thian-Shan, Ala Tau, and Altai mountains all bear on their flanks strata of middle Tertiary age, now elevated to a height of more than 10,000 feet.

2. The existence of lake Baikal is an indubitable witness to the recency of some of these extensive changes. This lake, 400 miles long and with an average width of 30 miles, occupies a depression on the western side of the Vitim plateau, and lies directly athwart the drainage basin of the Selenga river. The lake is surrounded on every side (except where the Angara river issues from it) by mountains rising from 2,000 to 5,000 feet above its surface. Its elevation above the sea is 1,580 feet, but near its southern end its depth is 4,180 feet. The drainage basin of the Selenga river, whose sediment is swept into the south end of the lake, is fully 200,000 square miles in extent, the most of which is more than 3,000 feet above the surface of the lake, giving a very steep gradient for the streams. The main river, with all its tributaries, now occupies deep trenches of erosion in granitic and archean rocks. These trenches are in their lower courses 2 or 3 miles in width and a thousand or more feet in depth, representing an immense period of time. But nearly all of them contain sedimentary strata at the bottom, sometimes 100 feet or more in thickness, of Tertiary age.

A brief calculation only is required to show that the formation of that portion of the lake basin which receives the sediment of the Selenga river, belongs to very recent geological time; for, at the most moderate rate at which it can be supposed that the erosion in this valley is proceeding, the whole southern half of lake Baikal would be filled with sediment in less than 500,000 years, whereas it is certainly not one-quarter full. Briefly stated, the calculation is as follows: Estimating the length of that part of the basin receiving the sediment to be 200 miles, the breadth 40 miles, and the average original depth one-half mile, all of which figures are in excess of the reality, the basin to be filled would contain 4,000 cubic miles. At the rate with which erosion is proceeding in the Mississippi valley, namely, the removal of one foot from the entire surface in 5,000 years, 40 cubic miles of sediment would be brought into the lake by the Selenga river in that period of time; so that in 500,000 years the whole work of filling it would be accomplished.

The estimate concerning the extent to which the sedimentation has already proceeded is based somewhat on the size of the delta at the mouth of the Selenga river. This approximately has a base of 30 miles along the shore of the lake, with an average width of less than 10 miles, while over much of this area the thickness of the deposit is evidently



REMNANTS OF LOESS MASS NEAR RAILROAD STATION, TASHKENT, TURKESTAN

About one hundred feet high

not great. The whole area occupied by this delta above the water is not over one-twentieth that of the portion under consideration, while if we estimate the amount which has been carried into the lake beyond the shoreline as four times this amount, that would only result in one-fifth of the work required to fill the whole basin, thus bringing the actual time down to 100,000 years, while, on account of our probable overestimate of the thickness of the deposit in the delta, the total amount of work done is doubtless much overestimated, bringing the date down to still lower limits; but however much one should lengthen this estimate, it must remain the clearest and most definite evidence yet brought to notice of the recency of some of the extensive changes connected with and following the close of the Tertiary period.

3. Other evidence concerning the recency of these great changes in northern and central Asia appears in the more definite witness of recent shoreline deposits of gravel at an elevation of 600 or 700 feet in widely separated regions. One of these is reported by J. Stadling* near the mouth of the Lena river and 10 miles back from it, where he found, 600 feet above the sea, "in a layer of soil composed of turf and mud mixed with sand, resting on a foundation of solid ice as clean and blue as steel and of unknown depth, large quantities of driftwood, evidently brought down by the river at the remote period when it had its course here." Another is one, which I have elsewhere described,† at Trebizond, on the Black sea, where a large amount of fresh-looking beach gravel is found clinging to the precipitous side of the volcanic rocky mass back of the city at an elevation of 750 feet above the sea. Still another instance, which I have described in the same paper, is in the lower part of the Dariel pass, on the north side of the Caucasus mountains, where there are extensive fluviatile deposits of such character as to indicate a great change in the relative level of the gorge in correspondingly recent times. In conformity with this, Professor Charles W. Keyes tells me that he has observed extensive raised beaches of corresponding height to those of Trebizond at Soudak, on the north shore of the Crimea.

All these things point to the fact that in those epeirogenic movements which characterized the latter part of the Tertiary and the whole of the Glacial period, there was a brief subsidence of the Asiatic continent—central Asia, perhaps, playing see-saw with northwestern Europe and America, the one going down while the other went up. But, however that might be, at some stage during this late period of geological instability, a general depression of central Asia must have occurred to account for the phenomena we have presented, distributing the loess in the peculiar manner indicated and filling the central depression of Mongolia with an interior sea.

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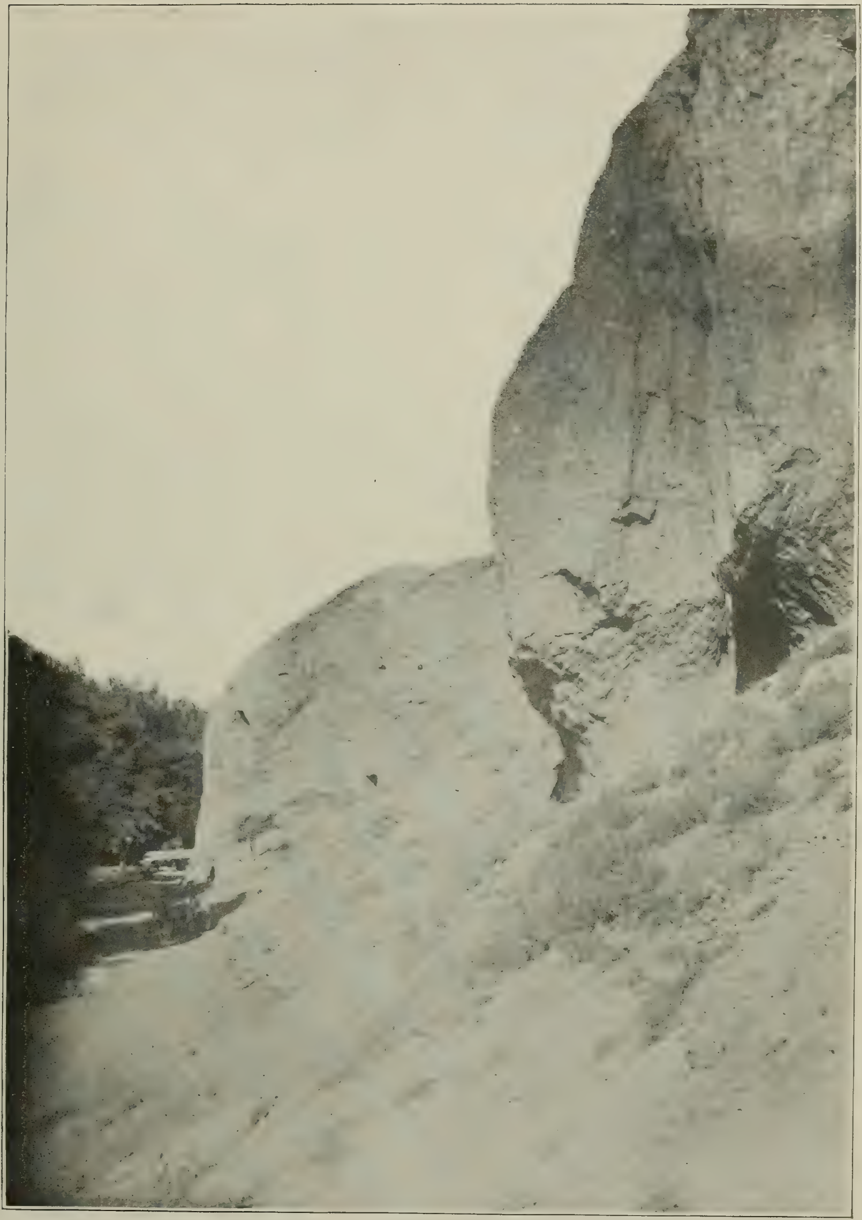
*See J. Stadling: Through Siberia, p. 161. New York, 1901.

†See Quarterly Journal, Geol. Society, vol. 57, 1901, p. 249.

Additional confirmatory Evidence

This theory has the advantage of accounting at the same time for the peculiar distribution of arctic species of seal from the elevated basin of lake Baikal (1,600 feet above the sea) to the isolated Aral and Caspian seas in western Turkestan. It also helps to account for the innumerable evidences that, up to comparatively recent times, there was an immensely greater rainfall over central and western Asia than there is at the present time. For example, it is above all question that up to a comparatively recent time, say 10,000 or 15,000 years ago, the depression of the Jordan valley was filled with water 750 feet above the present level of the Dead sea. The comparative freshness of lake Balkash and of the Aral and Caspian seas likewise indicate a recent rainfall in that region far in excess of the present. In the absence of glacial conditions in the proximity of these seas, this would seem to be best accounted for by the additional supply of moisture to the atmosphere which would have been furnished from the evaporating surface of extensive inland seas in the center of Mongolia and in other depressed areas in Asia.

The discussion should not be closed, however, without remarking that ample credit must still be given to the wind as an agency which is still at work distributing the loess and producing many minor modifications which are plainly visible in northeastern China, where many of the extensive deposits are clearly drifted material brought in by the wind in recent times. This may be freely granted without admitting that wind is competent to account for all the phenomena presented.



LOESS EXPOSURE TWO MILES EAST OF SAMARKAND

About one hundred feet high

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
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FORMER EXTENT OF THE NEWARK SYSTEM

BY WILLIAM HERBERT HOBBS

(*Presented before the Society January 2, 1902*)

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VIEWS HELD BY AMERICAN GEOLOGISTS

American geologists have quite generally held to the view that the former extent of the Newark system along the Atlantic border was not much greater than at present, the assumption being made that the deposits were laid down in local basins practically coextensive with the present Newark areas. Russell alone of those who have made special study of the system has advocated a "broad terrane" as against a "local basin" hypothesis for the origin of these deposits.* Davis has expressed the view that the Newark trough of the Connecticut valley was at least 8 or 10 miles wider than the present valley,† but he has thrown the weight of his authority in favor of a strictly "local basin" of deposition. Shaler and Woodworth in their joint monograph treating of the Richmond basin discuss the evidence from that area without reaching a very definite conclusion, though they seem to favor the generally accepted view.*

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* I. C. Russell: On the physical history of the Triassic formation in New Jersey and the Connecticut valley. Ann. N. Y. Acad. Sci., vol. i, 1879, pp. 220-254.

See also The Newark system, Bull. 85, U. S. Geological Survey, chap. ix, pp. 101-107.

† W. M. Davis: The Triassic formation of Connecticut. Eighteenth Ann. Rep. U. S. Geological Survey, 1898, pt. ii, p. 37.

The following statement, however, is made in their report:

> "It is evident that the field now occupied by the Newark beds of the Richmond basin was at one time much more extensive than it is at present. Its extreme limits cannot well be determined. As is well known, the eastern margin of the field is bordered by several small detached areas, in which are preserved the lower coal-bearing strata. . . . It is not improbable that small basins similar to the Black Heath lie beneath the common mantle of residual deposits as far to the east as the meridian of Richmond, or, say 12 miles from the ascertained exposures of the Newark series. . . .
>
> "The distribution of the remaining portions of the Newark beds in Virginia is consistent with the hypothesis that the deposits once mantled that field over, the several areas still existing owing their preservation to their inclusion in the troughs arising from the dislocation of the basement. It is also reconcilable with the supposition that the beds were laid down in preexisting valleys, the lesser basins grouped about the greater being peripheral remnants of the once more extended areas." †

Dr Woodworth, in a personal letter to the writer, says:

> "I am rather inclined to a broad terrane distribution of the Newark for the upper and lower middle sections where I have seen them. I suspect the geography was somewhat like that of the Great Basin, and that enormous denudation has taken place."

Explanation of general Acceptance of "Local Basin" Hypothesis

To the writer it seems that the general adhesion to the "local basin" hypothesis on the part of geologists who have studied the Newark system, may have its explanation in the position from which the study has been approached and the manner in which the investigations have been conducted. The first continuous terrane hypothesis—that of Rogers for the areas south of New York—was so unsatisfactory as to prejudice more or less the later theories which involved a continuous terrane. On the other hand, the early description of the Acadian area—the one really isolated Newark area—as a separate basin, with deposits formed in a bay swept by strong tidal currents, required little change from present conditions in the bay of Fundy, and possessed a large measure of probability. Le Conte and Newberry seem to have accepted the local basin hypothesis and given color to their writings in harmony with this view, so that the doctrine early acquired a considerable momentum from the weight of authority behind it. Of no little importance also as affecting the growth of opinion about the Newark is the fact that the numerous areas are geographic units and extend through a considerable number of states. Because of this the detailed study of the system has been undertaken by different geologists belonging to the several state surveys or to different divisions of the U. S. Geological Survey, and they have each studied one area or a portion of an area only.

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*N. S. Shaler and J. B. Woodworth: Geology of the Richmond basin, Virginia. Nineteenth Ann. Rep. U. S. Geological Survey, pt. ii, 1899, pp. 385–519.

† Op. cit., pp. 413, 414.

Reconsideration of Problem favored by recent Monographs

The "correlation paper" on the Newark system published in 1892 by the U. S. Geological Survey was the first serious attempt to correlate the work of the different areas. Since the appearance of that paper much more detailed study has been given to a number of the important areas. Moreover, the principles of structural geology, which have been strongly emphasized in the American work of the last decade, have been applied with success to the solution of the local problems.

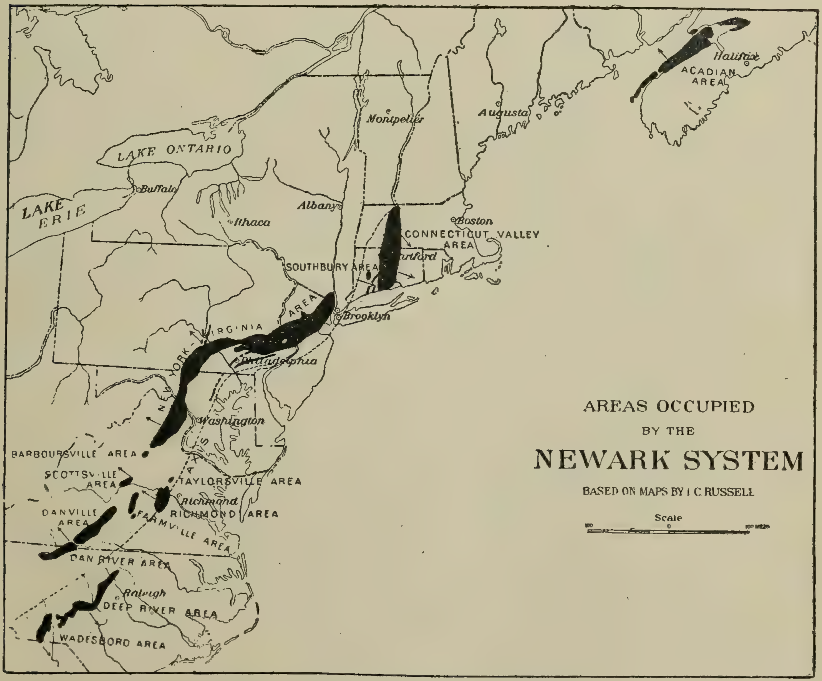
Halifax
ACADIAN AREA
Montpelier
Augusta
LAKE ONTARIO
Buffalo
LAKE ERIE
Albany
Ithaca
Boston
CONNECTICUT VALLEY AREA
Hartford
SOUTHBURY AREA
Brooklyn
NEW YORK–VIRGINIA AREA
Philadelphia
Washington
BARBOURSVILLE AREA
SCOTTSVILLE AREA
TAYLORSVILLE AREA
Richmond
RICHMOND AREA
DANVILLE AREA
FARMVILLE AREA
DAN RIVER AREA
Raleigh
DEEP RIVER AREA
WADESBORO AREA
AREAS OCCUPIED
BY THE
NEWARK SYSTEM
BASED ON MAPS BY I. C. RUSSELL
Scale

Figure 1.—*Area occupied by the Newark System.*

The last three years have seen the appearance of no less than five final reports treating in much detail the geology of the areas from New

England to Virginia.* They are the reports by Emerson on the Massachusetts portion of the Connecticut Valley area; by Davis on the Connecticut portion of the same area; by Kümmel on the New York-New Jersey area; by Shaler and Woodworth on the Richmond area, and by the writer on the Pomperaug Valley area. Keith's study of the Catoctin belt had appeared in 1894.† These extended investigations make possible a review of the subject of Newark conditions of deposition and the area over which they extended.

Local Basin versus "Broad Terrane" Hypothesis

"LOCAL BASIN" HYPOTHESIS

The observed phenomena which the "local basin" hypothesis has been framed to explain, seem to be: (1) The present occurrence of the terrane in circumscribed areas separated by other and generally older horizons; (2) the nature of the sediments, which indicate shallow and brackish water deposition, and, (3) the occurrence of coarse arkose and conglomerate, interpreted to indicate that powerful transporting agencies were at work when these sediments were deposited.

The new light thrown on the problem by recent studies, in the opinion of the writer, furnishes the data for a more satisfactory explanation of these phenomena on the basis of a continuous and broad area of deposition, at least for all save the Acadian area.

MARGINAL FAULTS FAVOR "BROAD TERRANE" HYPOTHESIS

The most important single line of observations derived from the recent studies and bearing upon the problem, is that which shows that all the areas recently studied are largely surrounded by observed faults or by probable faults, and that the Newark terrane is generally at a lower level than the older rocks by which it is surrounded. This result was foreseen by Russell in the trend of his own and other observations at the time his correlation paper was published, but the close agreement of the recent observations may well be emphasized. The accompanying sketch maps, reproduced from the several monographs, will indicate how general is the agreement which has been reached. The writer has modified the sketch of the New York-New Jersey area by adding a fault along the eastern margin of the Palisades, because not only does the topographic break at the border of the system seem to require such a fault, but parallel faults observed by the writer during the past summer on New York island increases the probability of this structural break. The object of the diagrams being simply to show the nature of the Newark boundaries as determined by the different observers, violence has been done in reproducing to the comparative scales of the areas concerned as convenience has dictated.

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*W. M. Davis: The Triassic formation of Connecticut. Eighteenth Ann. Rep. of U. S. Geological Survey, pt. ii, 1898, pp. 1-192.

B. K. Emerson: Geology of old Hampshire county, Massachusetts, comprising Franklin, Hampshire, and Hampden counties. Monograph 29, U. S. Geological Survey, 1898, pp. 351-501.

H. B. Kümmel: The Newark system of Red Sandstone belt (in New Jersey). Ann. Rep. State Geologist of New Jersey for 1897. Trenton, 1898, pp. 25-159.

H. B. Kümmel: The extension of the Newark system of rocks (in New York). Ann. Rep. State Geologist of New Jersey for 1898. Trenton, 1899, pp. 43-57.

N. S. Shaler and J. B. Woodworth: Geology of the Richmond basin, Virginia. Nineteenth Ann. Rep. U. S. Geological Survey, pt. ii, 1899, pp. 385-519.

W. H. Hobbs: The Newark system of the Pomperaug valley, Connecticut, with a report on fossil wood by F. H. Knowlton. Twenty-first Ann. Rep. U. S. Geological Survey, pt. iii, 1901, pp. 1-162.

†Arthur Keith: Geology of the Catoctin belt. Fourteenth Ann. Rep. U. S. Geological Survey, pt. ii, 1894, pp. 345-385.

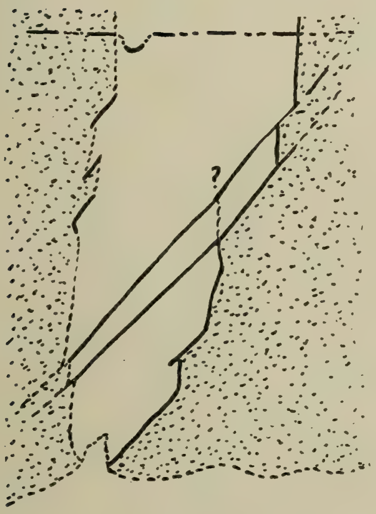

Figure 2.—*Sketch Map of southern Part of Newark Area of Connecticut Valley.*

After Davis. Full lines represent faults.

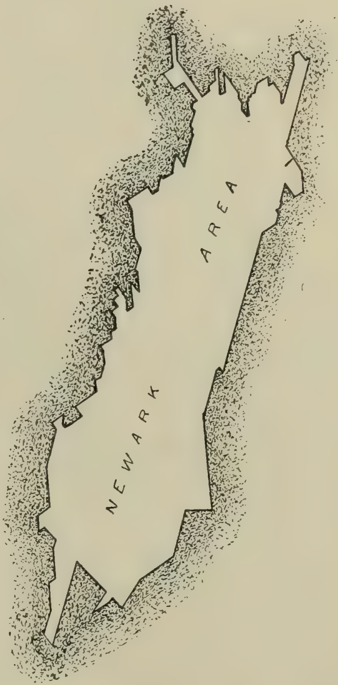

Figure 3.—*Sketch Map of Newark Area of Pomperaug Valley, Connecticut*

Full lines represent faults.

The general observation of marginal faults, considered with reference to the probability that many have eluded observation, and also with respect to the generally lower position of the Newark terrane, makes it extremely probable that the several areas have been depressed along fault walls below the baselevel of erosion, and hence preserved where we now find them. Their local occurrence would thus be fully accounted for.

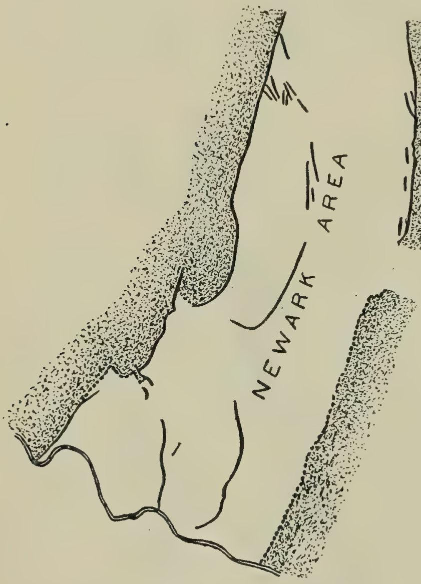

Figure 4.—*Sketch Map of Newark Area of New York and New Jersey.*

Based on maps by Kümmel. Full lines represent faults.

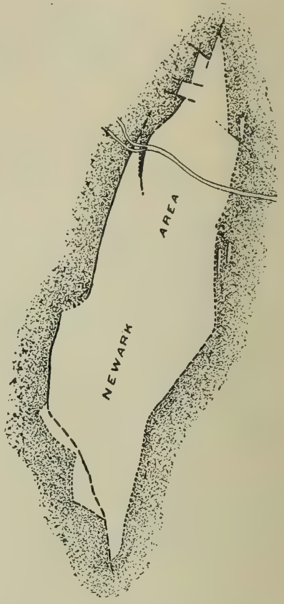

Figure 5.—*Sketch Map of Newark Area of Richmond Basin.*

After Shaler and Woodworth. Full lines represent faults, ashed lines probable faults.

Attempt to Picture Newark Conditions of Deposition

COARSENESS OF SEDIMENTS

The coarseness of the Newark sediments, and especially the occurrences of arkoses and giant conglomerates, furnish the greatest obstacle to forming a picture of the Newark period, a powerful transporting agent being generally assumed to be necessary to explain the distribution of these conglomerates. The tides of a deep bay or estuary having steep walls has been the most frequently assumed. In the more recent work Emerson has invoked this condition to explain the deposition within the Massachusetts area, southern New England being supposed a Rias coast and the Connecticut valley a deep, fjord-like bay into which the sea was admitted on a thick mantle of disintegrated rock material which its strong tides took up and transported.*

DISTRIBUTION OF THE CONGLOMERATES

The distribution of the conglomerates is one possessing very considerable interest. In the Connecticut Valley area these rocks generally form an eastern and northern and sometimes a western border to the area. In the New York-New Jersey area they form likewise a border, but on the northwest. In the southern areas also, as well as within the small Pomperaug Valley area of Connecticut, they are generally marginal to the areas as respects their distribution. So general is this observation that the few cases where the exposures of conglomerate are found distant from the boundaries of the areas, may generally be best explained through displacement by the block-faulting which has everywhere prevailed. Within the Mount Toby conglomerate area of the Connecticut valley, which is somewhat removed from the margins of the Newark of that region, Emerson † found islands of crystalline rocks, from which the material could have been derived. The material of the Newark conglomerates is almost entirely derived from the metamorphic rocks by which they were surrounded. The general lack of correspondence between the material of the conglomerates and that of the contiguous portion of the wall of crystallines has led Emerson to appeal in part to shore ice and in part to transportation by strong tidal currents, which, in the Connecticut Valley area, he supposes to have moved northward along the western wall and returned along the eastern border of the area. An even more marked lack of correspondence along the northwestern border of the New York-New Jersey area, Kümmel would explain by vertical displacement along fault-walls, a theory which might, it would seem, be applied with equal force to the Connecticut Valley area. In the southern areas the conglomerates seem to be most abundant along the western margins of the areas, and it may be said that the distribution of the conglomerates, as regards the areas as a whole, seems to be best accounted for, and, in fact, the formation has been generally described, as a basal conglomerate of the system. Outside of New England its general restriction to the western borders (without regard to the displacement by faulting) is most in accord with this view, if the western border of the province in which Newark areas occur be regarded as near the western margin of a large area of Newark deposition, owing to the initial dip of the formation. This explanation is also in harmony with the now generally accepted view that the Newark boundaries are largely along faults, for the lower beds of the system will occur nearest the boundaries, due to the distribution of the displacement at their boundaries over a series of near-lying planes.

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*Op. cit., p. 373.

†Op. cit., pp. 361–363.

GEOGRAPHIC CONDITIONS

It is difficult to picture the conditions which prevailed in Newark times, but the peculiar occurrence and distribution of this basal conglomerate may perhaps be accounted for if a broad land area of the crystalline rocks were subjected to long-continued secular disintegration in an arid climate, and subsequently depressed so as to admit the sea. The deeply disintegrated rock masses would in the higher areas, where the waves and tidal currents were effective, be washed free from the finer material, and in consequence the pre-Newark land areas would be mantled by a coarse arkose or conglomerate whose pebbles would have only slightly rounded surfaces. The borders of the area and the island peaks and ridges which projected above the water surface would therefore be surrounded by marginal zones of greater or less width made up of conglomeratic material. In the deeper areas sandstone and shale would be deposited. Where coarse pegmatites occurred giant conglomerates composed of large feldspars would locally be produced, as has been the case, particularly in the New England areas. To these New England areas the hypothesis fits particularly well, because of the distribution of the Mount Toby conglomerates, as described by Emerson,* and the character of the Roaring Brook contact on the crystallines, as described by Davis,† the irregular surface of the latter, and the local derivation of the Newark material strongly favoring the view.

It is not necessary to assume that the pre-Newark terrane was in all parts depressed below sea level. The southern areas, with their coal formations, indicate marshy areas with rank vegetation. If a geography not unlike that of the great basin be pictured, with a change of climatic conditions, the torrential streams from the steep walls and from the island-like peaks and ridges may be appealed to for the sorting of the sediments and the local transportation of the large rock fragments of the conglomerate, as has been already suggested by Shaler and Woodworth.‡

The above review of the character and the distribution of the coarse sediments has been somewhat fully considered, because they have been so generally interpreted as requiring that the Newark deposits be formed in local basins.

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* Op. cit., p. 361.
† Op. cit., pp. 19-23.
‡ Op. cit., pp. 404-406.

CONDITIONS FAVORABLE TO A BROAD TERRANE

There are, however, some considerations other than the occurrence of marginal faults which favor the broad and continuous terrane hypothesis. Five of them may be stated as follows:

1. The several areas, with the exception of the Acadian area, are now so nearly connected that if they were inclosed by a line which continued the outer margin of each to the nearer areas on either side, the area included which was unoccupied by Newark deposits would about equal that thus occupied.

2. The remarkable resemblances observed to characterize near-lying Newark areas and the rather marked differences noted between areas widely separated indicate a distinct gradation in characteristics from those peculiar to northeastern to those peculiar to southwestern areas. These gradations are noted in the character of the deposits, in the nature of the life remains, in the manifestations of volcanic activity, etcetera.

3. The enormous degradation which all observers agree has taken place since the deposition of the Newark sediments, favors the view that the present areas are only remnants of a much larger area of deposits, these remnants owing their preservation to their depression below the baselevel of erosion and within the protecting walls of crystalline rocks.

4. The community of structural peculiarities within the different areas and the relations observed between the eastern and the western areas of the sinuous double belt is not without significance. As early pointed out by Russell,* the Connecticut valley and the northern portion of the New York-Virginia area, as regards the sequence of their deposits and the nature and the order of the included basalt layers, seem to represent the opposite limbs of an imbricated fold, the parts of which have been preserved by depression along fault planes within the crystalline rocks. Less noteworthy relationships are indicated in the prevailing dips within the southern areas which lie to the east and those to the west of an axial line (see figure 1).

As the sinuous trend of this depressed double trough follows throughout its extent the axis of Appalachian folding, it is easy to understand how the Newark system might be preserved in this belt and not elsewhere, even if its deposits had once extended far to the east.

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*I. C. Russell: On the physical history of the Triassic formation in New Jersey and the Connecticut valley. Ann. N. Y. Acad. Sci., vol. i, 1879.

5. The rivers of Connecticut by their orientation appear to betray a relation to certain of the fault directions as worked out in the Pomperaug Valley area, within which and about which such a connection can be clearly shown.* A causal relationship of the one to the other is not difficult to conceive, provided the streams began their cutting in the Newark sediments, which easily sustain fractures along fault planes.

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*Cf. Hobbs: Twenty-first Ann. Report U. S. Geological Survey, 1901, chap. v. Journal of Geology, vol. ix, 1901, pp. 469-484. Science, vol. xiv, 1901, pp. 1011, 1012.

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HAMILTON GROUP OF THEDFORD, ONTARIO

BY HERVEY W. SHIMER AND AMADEUS W. GRABAU

(Presented before the Society December 31, 1901)

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INTRODUCTION

The following notes on the stratigraphic and faunal succession in the Hamilton group of the Thedford region were made during a short visit to that locality in the summer of 1901. They are intended merely as a contribution to the geology of that well known and often visited region, which still awaits a comprehensive and detailed study. It was our good fortune while at Thedford to make the acquaintance of Messrs Aldridge, N. J. Kearney, and Charles Southworth, of Thedford, students of the local geology. They generously conducted us to the most interesting sections in the vicinity and aided us in making the collection on which our study is based.

DESCRIPTIONS OF THE SECTIONS

IN GENERAL

We visited in all five sections in the Thedford region. These are:

A. The cut about a quarter of a mile east of the Thedford station, on the Grand Trunk railroad.

B. An exposure on the hillside (old river bank) about three-quarters of a mile north of the preceding locality.

C. The banks of a small stream about a mile west of the preceding locality. The clay of the lower beds is here dug for brick manufacture.

D. Rock glen, about a mile east of Arkona, on a small tributary of the Rivière aux Sables.

E. Bartletts mills, now known as Marshalls mills, about a mile up the Sable river from the mouth of Rock glen.

In all of these exposures except the first a bed of limestone of nearly constant thickness and uniform character is found. This bed, generally called the Encrinal limestone, is readily recognized and serves as a datum plane for the correlation of the beds above and below it. It marks the dividing line between the upper and lower beds of the Hamilton group of this region, a division which is based on abrupt faunal changes.

SECTION A—THEDFORD

This section is now largely overgrown, the banks being much weathered, the shales changed to clays, and the calcareous beds shattered into fragments, which cover the slopes. The fossils are weathered out, and may be picked up in large quantities from the sloping bank. The most abundant form is *Spirifer mucronatus* var. *thedfordensis.* This section is between 30 and 40 feet deep, and may be divided as follows in descending order:

9. Argillaceous thin-bedded limestones and calcareous shales, the former containing chiefly fragments of brachiopods, as well as complete shells and numerous branches of *Ceratopora intermedia* (Nicholson) and *Streblotrypa hamiltonense*	10 feet

The following is a list of species obtained from these beds: *

---

* The numbering refers to the table at the end of the paper.

3. *Phacops rana* Green.
4. *Cryphæus boothi* Green.
8. *Primitiopsis punctulifera* (Hall).
12. *Goniatites* cf. *uniangularis* Conrad.
Orthoceras sp.
19. *Tentaculites attenuatus* Hall, var.
40. *Aviculopecten princeps* (Conrad).
60. *Stropheodonta concava* Hall.
61. *Stroph. demissa* (Conrad).
62. *Stroph. inequistriata?* (Conrad).
64. *Pholidostrophia iowaensis* (Owen).
65. *Leptostrophia perplana* (Conrad).
68. *Orthothetes arctostriata* Hall.
69. *O. perversa* Hall.
71. *Chonetes lepida* Hall.
81. *Pentamerella papillionensis* Hall.
87. *Leiorhynchus laura* (Bill.).
97. *Atrypa reticularis* (Linn.).
105. *Spirifer mucronatus* var. *thedfordensis* S. and G.
107. *S.* cf. *consobrinus* d'Orbigny.
118. *Athyris fultonensis* (Swallow).
137. *Paleschara?* sp.
138. *Streblotrypa hamiltonensis* (Nich.).
155. *Fistulipora utriculus* Rominger.
206. *Ceratopora intermedia* (Nicholson).
207. *C. nobilis* (Billings).

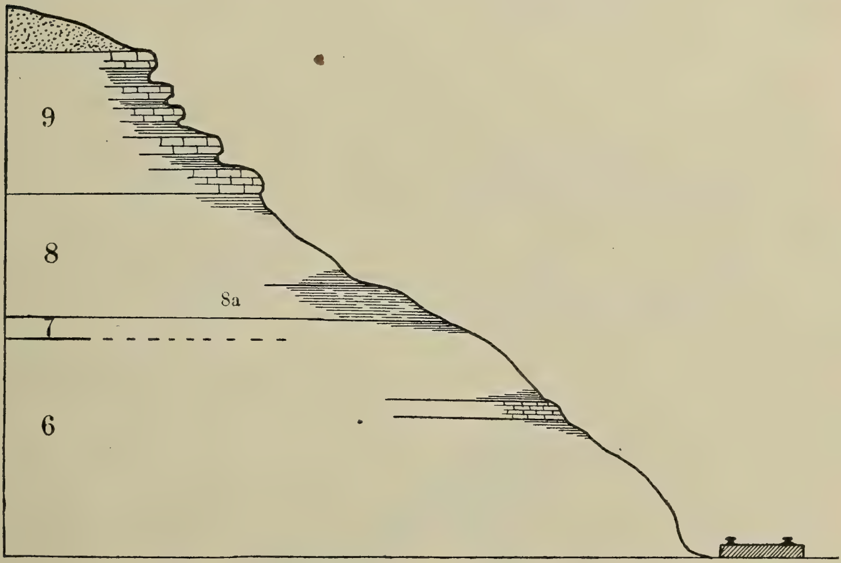

FIGURE 1.—*Section A—One Side of Railroad Cut near Thedford.*

Figures as in text. For scale see figure 4.

8 and 7. Gray calcareous shale full of *Spirifer mucronatus* var. *thedfordensis*, which appears to be mostly confined to a stratum 4 feet thick in the lower bed 8; (8*a*).. 10 feet

The following species were found on the talus slope, and probably belong to beds 7 and 8:

8. *Primitiopsis punctulifera* (Hall).
10. *Barychilina walcotti* Jones.
36. *Pleurotomaria* cf. *arkonensis* Whiteaves.
60. *Stropheodonta concava* Hall.
71. *Chonetes lepida* Hall.
87. *Leiorhynchus laura* Bill.
105. *Spirifer mucronatus* var. *thedfordensis* S. and G.

111. *Cyrtina hamiltonensis* Hall.
112. *C. hamiltonensis* var. *recta* Hall.
119. *Athyris* cf. *spiriferoides* (Eaton).
118. *A. fultonensis* (Swallow).
122. *Meristella rostrata* Hall.
143. *Reteporina prisca* Nich.
155. *Fistulipora utriculus* Rom.
163. *Hederella canadensis* (Nicholson).
165. *H. filiformis* Nicholson.
170. *Spirorbis arkonensis* Nich.
171. *Spirorbis omphalodes* Nicholson.
204. *Aulopora serpens* Rominger.
206. *Ceratopora intermedia* (Nicholson).
209. *Trachypora elegantula* Billings.

6. Blue clay, poorly exposed and poor in fossils ....exposed portion.. 10 feet

This section is entirely above the Encrinal limestone, and therefore belongs to the Upper Hamilton of this region. It is described by Logan on page 385 of his report. He says that the whole section abounds in fossils, but this does not hold for the lower beds, though their slopes are covered with weathered-out fossils from the beds above.

SECTION B

This section exposes the Encrinal limestone, which is about 2 feet thick and is divided into three beds. It was formerly quarried at this point. Just above the limestone is the coral layer, a decomposed shale full of corals, which are weathered out and may be picked up in large numbers on the surface. The most abundant and characteristic corals are: *Heliophyllum halli* E. and H., *H. tenuiseptatum* Billings, *Craspedophyllum subcæspitosum* (Nicholson), *Cystiphyllum vesiculosum* (Goldfuss), *Favosites billingsi* Rominger, and *F. placenta* Rominger. Calvin (1888) cites *Microcyclus discus* Meek and Worthen as occurring in this division of the series, but this is probably a mistake. No specimens were found in this exposure, the most typical of the coral layer, but the species is not uncommon at the base of the section at Bartlett's mills, and undoubtedly belongs to the lower beds.

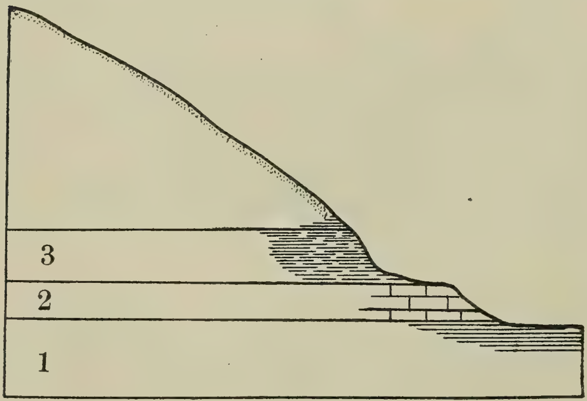

Figure 2.—*Section B—North of Thedford.*

Figures as in text. For scale see figure 4.

The following is the list of species found at this locality; all belong to the coral layer, or middle division of the Hamilton group:

3. *Phacops rana* Green.
15. *Orthoceras* cf. *lambtonense* Whiteaves.
31. *Orthonychia* (*Platyceras*) *conicum* Hall.
32. *Diaphorostoma lineata* (Conrad).
58. *Craniella hamiltoniæ* (Hall).
60. *Stropheodonta concava* Hall.
61. *Stroph. demissa* (Conrad).
64. *Pholidostrophia iowaensis* (Owen).
79. *Rhipidomella penelope* Hall.
80. *Rh. vanuxemi* Hall.
84. *Camarotœchia thedfordensis* Whiteaves.
91. *Cyclorhina nobilis* Hall.
92. *Eunella attenuata* Whiteaves.
97. *Atrypa reticularis* (Linn.).
105. *Spirifer mucronatus* var. *thedfordensis* S. and G.
111. *Cyrtina hamiltonensis* Hall.
114. *Nucleospira concinna* Hall.
117. *Parazyga* cf. *hirsuta* Hall.
143. *Reteporina prisca* Nich.
171. *Spirorbis omphalodes* Nich.
Crinoid joints.
186. *Nucleocrinus elegans* Conrad.
193. *Dolatocrinus* (spines).
204. *Aulopora serpens* Goldfuss.
205. *Monilopora antiqua* Whiteaves.
206. *Ceratopora intermedia* (Nich.).
208. *C. dichotoma* Grabau.
209. *Trachypora elegantula* Billings.
212. *Cladopora frondosa* Bill.
215. *Alveolites goldfussi* Bill.
218. *Favosites placenta* Rominger.
220. *F. turbinata* Bill.
221. *F. billingsi* Rom.
222. *F. alpenensis* Winchell.
Zaphrentis sp.
225. *Z. prolifica* Bill.
227. *Cyathophyllum conatum* Hall.
228. *C.* cf. *robustum* Hall.
230. *Heliophyllum halli* E. and H.
231. *H. tenuiseptatum* Bill.
233. *Craspedophyllum subcæspitosum* (Nich.).
237. *Cystiphyllum vesiculosum* Goldfuss.
238. *C. conifollis* Hall.

Stratigraphically section B is below section A.

SECTION C—BRICKYARD

The section here exposed comprises the following strata in descending order:

Drift	1 foot
3. Clay, mingled with drift, full of corals of the same type as those found at section B, this being in fact the disintegrated "coral layer"	2 feet
2. Encrinal limestone in several beds, the lowest separated from those above by a two to four inch bed of black shale full of crushed shells of Leiorhynchus (2*b*)	3 feet
1. Blue, apparently non-fossiliferous clay	15 feet

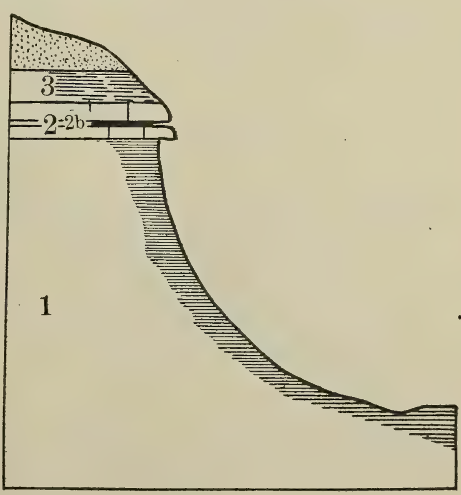

Figure 3—*Section C—Brickyard.*

Figures as in text. For scale see figure 4.

The coral bed is rich in *Spirifer mucronatus* var. *thedfordensis*. This and the corals cover the slopes of the bank. The following list comprises the species picked up in a brief time, and is, of course, not an exhaustive one:

28. *Platyceras subspinosum* Hall.
57. *Crania cranistriata* Hall.
59. *Pholidops hamiltoniæ* Hall.
64. *Pholidostrophia iowaensis* (Owen).
71. *Chonetes lepida* Hall.
79. *Rhipidomella penelope* Hall.
84. *Camarotœchia thedfordensis* Whiteaves.
86. *Trigeria lepida* Hall.
97. *Atrypa reticularis* (Linn.).
105. *Spirifer mucronatus* var. *thedfordensis* S. and G.
111. *Cyrtina hamiltonensis* Hall.
114. *Nucleospira concinna* Hall.
115. *Cryptonella* sp.
116. *Rhynchospira eugenia* (Bill.).
136. *Semicoscinium labiatum* Hall.
139. *Fenestella* cf. *arkonensis* Whiteaves.
143. *Reteporina prisca* Nicholson.
155. *Fistulipora utriculus* Rominger.
209. *Trachypora elegantula* Bill.
212. *Cladopora frondosa* (Bill.).
213. *Cl. roemeri* (Billings).
214. *Striatopora linneana* Bill.
215. *Alveolites goldfussi* Bill.
217. *Favosites digitata* Rom.
218. *F. placenta* Rom.
219. *F. clausa* Rom.
230. *Heliophyllum halli* E. and H.
231. *H. tenuiseptatum* Bill.
233. *Craspedophyllum subcæspitosum* (Nich.).
237. *Cystiphyllum vesiculosum* Goldfuss.

The limestone consists of crinoidal fragments mingled with fragments of brachiopoda. *Spirifer sculptilis* was found in it.

The black shale which separates the lower 8 inches of limestone from the upper beds is filled with crushed valves of *Leiorhynchus laura* Bill.

The lowest beds comprise a blue homogeneous clay or weathered shale, with the stratification well marked, and almost destitute of fossils. It is supposed to be at least 30 feet thick, and is sufficiently uniform and free from lime to make good red bricks and tiles.

SECTION D—ROCK GLEN

In Rock glen the following section was measured in descending order:

Drift.

9. Bluish argillaceous limestone, often bituminous, containing many Bryozoa and fragments of trilobites, in beds from 1 to 2 feet thick and separated by beds of blue calcareous shale. Some of the beds are filled with fragments of *Ceratopora intermedia* (Nicholson)........... 9 feet
8. Gray calcareous shales, with numerous small lime concretions disposed in tiers. The lowest two feet abound in the characteristic Thedford Spirifer.. 8 feet
7. Blue argillaceous limestone containing a few *Spirifer mucronatus* var. *thedfordensis*, but scarcely any other fossils........................ 1½ feet
6. Blue calcareous shale, including, four feet from the top, a foot or more of harder calcareous beds. Fossils are rare, excepting a few specimens of the characteristic Thedford Spirifer........................ 18 feet

5.	Calcareous shales and shaly blue limestones containing *Phacops rana*	6 feet
4.	Argillaceous limestone	1 foot
3.	"Coral layer," a shaly and somewhat calcareous rock, full of fossils, among which Heliophyllum and Cystiphyllum predominate	3¼ feet

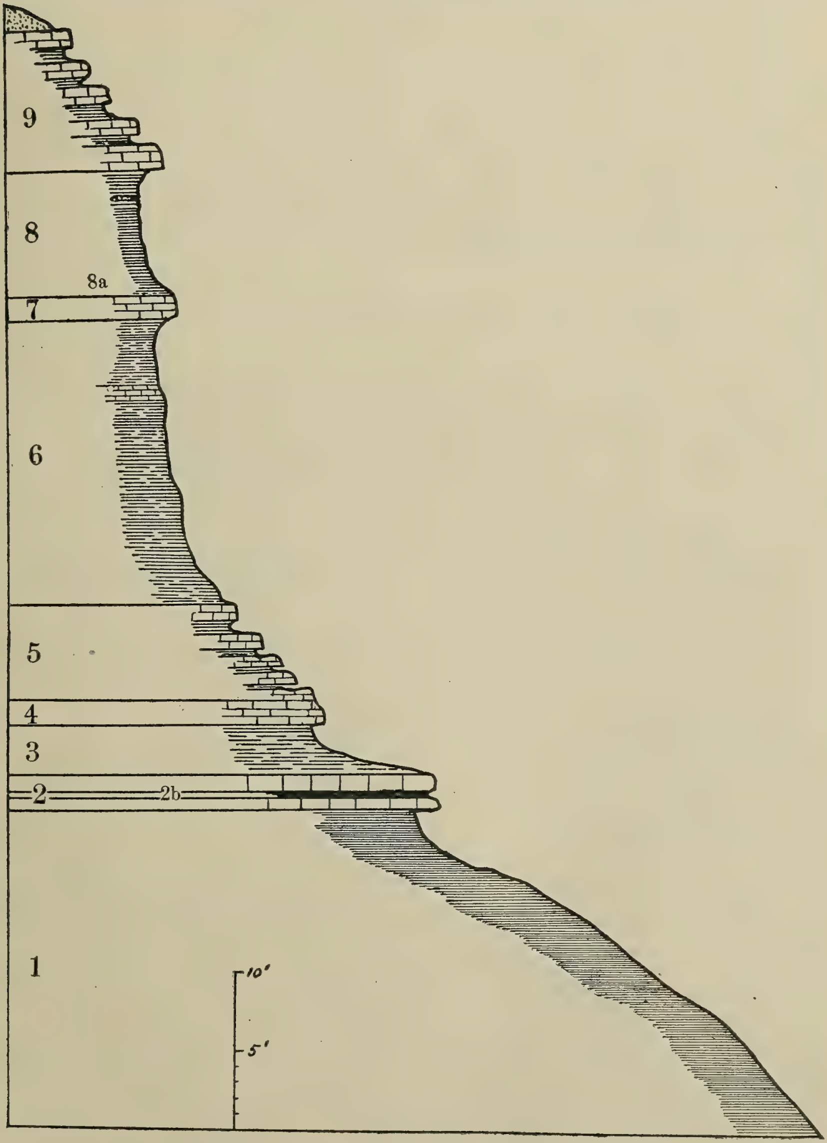

Figure 4.—*Section D—Wall of Rock Glen, near Arkona.*

Figures as in text.

2. Encrinal limestone, coarsely crystalline, heavy-bedded, and consisting largely of crinoidal fragments mingled with coral sand. It is divisible as follows:
    - *c.* Compact crystalline crinoidal limestone, with *Spirifer sculptilis*, Favosites, *Leptostrophia perplana*, etc........................ 1½ feet
    - *b.* Black shale, with Leiorhynchus .... ¼ foot
    - *a.* Crinoidal limestone like (*c*)........................ ¼ foot

2 feet

This limestone forms a small fall at the foot of the larger fall which is caused by the upper calcareous beds.

1. Blue shales, apparently non-fossiliferous; thickness exposed, about... 20 feet

Total exposure of rock, nearly .... 70 feet

In a few fragments from the lower part of the upper beds (9) the following fossils were found:

3. *Phacops rana* Green.
8. *Primitiopsis punctulifera* (Hall).
105. *Spirifer mucronatus* var. *thedfordensis* S. and G.
138. *Streblotrypa hamiltonense* (Nicholson).
Crinoid joints.
206. *Ceratopora intermedia* (Nich.)

The following species were obtained from bed 5:

3. *Phacops rana* Green.
4. *Cryphæus boothi* Green.
61. ? *Stropheodonta demissa* (Conrad).

In the calcareous bed number 4 the following species were found:

3. *Phacops rana* Green.
4. *Cryphæus boothi* Green.
8. *Primitiopsis punctulifera* Hall.
21. *Styliolina fissurella* (Hall).
41. *Pterinea flabellum* (Conrad).
47. *Nuculites triqueter* Conrad.
Orthothetes sp.
65. *Leptostrophia perplana* (Conrad).
71. *Chonetes lepida* Hall.
75. *Chonetes vicinus* (Castelneau).
88. *Leiorhynchus huronensis* Nicholson.
105. *Spirifer mucronatus, thedfordensis* S. and G.

The following species were found loose at Rock glen and belong to the beds above the Encrinal:

79. *Rhipidomella penelope* Hall.
88. *Leiorhynchus huronensis* Nicholson.

In addition to these, the common corals of the coral layer were found with *Heliophyllum halli* E. and H. and *Cystiphyllum vesiculosum* Goldfuss predominating.

The following species were found in the Encrinal limestone at Rock glen:

79. *Rhipidomella penelope* Hall.
80. *Rhipidomella vanuxemi* Hall.
96. *Tropidoleptus carinatus* Hall.
99. *Sp. audaculus* (Conrad).
100. *Sp. divaricata* Hall.
108. *Spirifer sculptilis* Hall.
220. *Favosites turbinata* Bill.
232. *Craspedophyllum archiaci* (Bill.).

SECTION E—BARTLETTS MILLS

On the Rivière aux Sables the following section is exposed below the bridge at Marshall's mills (formerly Bartlett's mills):

6. Drift .... 10 feet
5. Gray shale, poor in fossils .... 3 feet
4. Bluish gray calcareous shale forming a resistant bed which caps the coral layer and stands out in relief. Some beds have their weathered

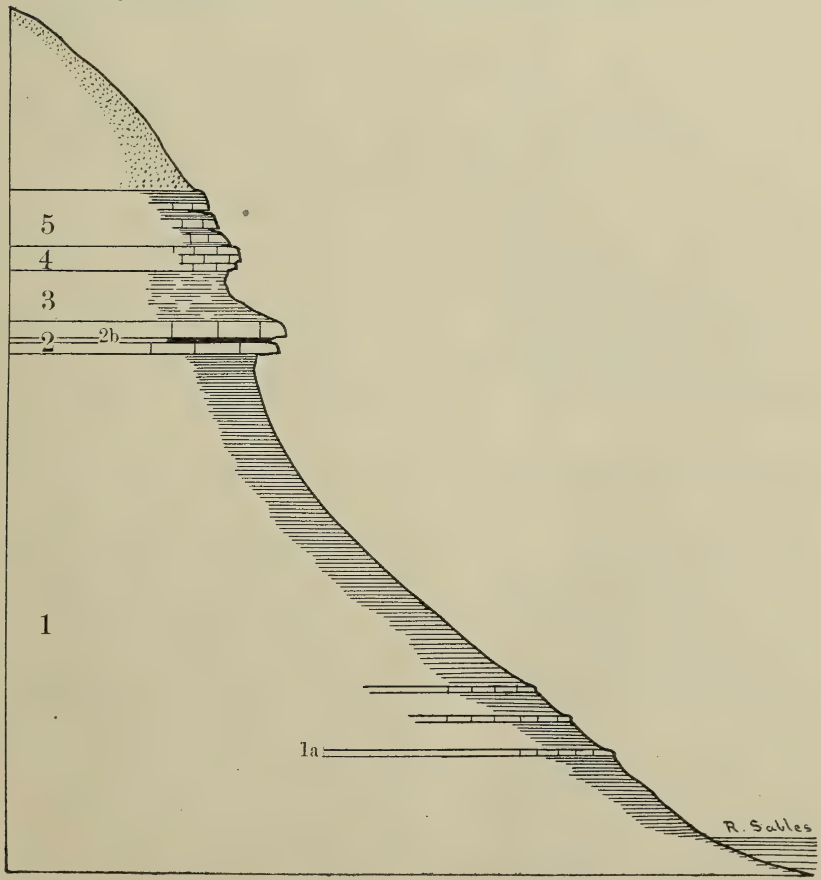

Figure 5.—*Section E—Bank of Rivière aux Sables at Bartlett's Mills* (*Marshall's Mills*): 1a=*Platyceras arkonense Bed.*

Figures as in text. For scale, see figure 4.

surfaces covered with minute shells of *Styliolina fissurella*, and *Primitiopsis punctulifera*. Chonetes, and other brachiopods also occur..... 1½ feet

This layer is also seen in Rock glen, where, near the mouth of the glen, it is conspicuous above the coral layer.

3. Coral layer, a decomposed shale full of the characteristic corals found in this layer in the other localities. *Spirifer mucronatus* var. *thedfordensis* is also common.. 3¼ feet
2. Encrinal limestone, the lowest bed of 4 inches is separated from the upper part by a 6-inch bed of black shale (2*b*)...................... 2 feet
1. Blue shale, poor in fossils except near the base........... .... 30+ feet

About 25 feet below the Encrinal limestone occurs a thin layer of limestone (1*a*) made up of fragments of crinoid stems and full of shells of a large variety of *Tentaculites attenuatus*, and containing, not infrequently, heads and plates of *Arthroacantha punctobrachiata*, as well as shells of *Platyceras arkonense*. The latter is often a common form, and not infrequently retains its long spines. This limestone layer is seldom over an inch or two in thickness. Other thin beds occurring in the lower 10 feet of the shale are made up of the shells of *Spirifer mucronatus* var. *arkonensis*, and not infrequently contain *Tentaculites attenuatus* and other fossils.

The following fossils were found in bed number 4:

4. *Cryphæus boothi* Green.
8. *Primitiopsis punctulifera* Hall.
19. *Tentaculites attenuatus* Hall (var.).
20. *T.* cf. *gracilistriatus* Hall.
21. *Styliolina fissurella* Hall.
41. *Pterinea flabella* (Conrad).
71. *Chonetes lepida* Hall.
74. *Chonetes scitula* Hall.
113. *Ambocœlia umbonata* (Conrad).

Crinoid joints.

The following species were found in the coral layer (bed 3) of Section E:

3. *Phacops rana* Green.
4. *Cryphæus boothi* Green.
8. *Primitiopsis punctulifera* Hall.
27. *Platyceras arkonense* S. and G., extreme old age form.
28. *Platyceras subspinosum* Hall.
30. *Platyceras quinquesinuatum* Whiteaves.
31. *Orthonychia conicum* (Hall).
41. *Pterinea flabella* (Conrad).
64. *Pholidostrophia iowaensis* (Owen).
65. *Leptostrophia perplana* (Conrad).
75. *Chonetes vicinus* (Castleneau).
78. *Productella* cf. *productoides* (Murchison).
79. *Rhipidomella* sp.
79. *R. penelope* (Hall).
84. *Camarotœchia thedfordensis* Whiteaves.
87. *Leiorhynchus laura* (Bill.).
97. *Atrypa reticularis* (Linn.).
103. *Spirifer mucronatus* (transition forms).
111. *Cyrtina hamiltonensis* Hall.
116. *Rhynchospira eugenia* (Bill.).
126. *Intrapora elegantula* (Hall).
162. *Botryllopora socialis* Nicholson.
163. *Hederella canadensis* (Nich.).
165. *H. filiformis* (Nich.).
186. *Nucleocrinus elegans* (Conrad).
209. *Trachypora elegantula* Bill.
211. *Cladopora* cf. *fischeri* (Bill.).

212. *Cladopora frondosa* (Bill.).
213. *Cladopora roemeri* (Bill.).
214. *Striatopora linneana* Billings.
216. *Roemeria ramosa* Whiteaves.
217. *Favosites digitata* Rominger.
218. *F. placenta* Rom.
219. *F. clausa* Rom.
220. *F. turbinata* Bill.
221. *F. billingsi* Rom.
225. *Zaphrentis prolifica* Billings.
226. *Cyathophyllum* cf. *zenkeri* Bill.
227. *Cyathophyllum conatum* Hall.
229. *Heliophyllum exiguum* Bill.
230. *H. halli* E. and H.
231. *H. tenuiseptatum* Bill.
233. *Craspedophyllum subcæspitosum* Nicholson.
237. *Cystiphyllum vesiculosum* Goldfuss.
238. *C. conifolle* Hall.
241. *Astræospongia hamiltonensis* M. and W.

In the Encrinal limestone *Spirifer sculptilis* Hall and *Favosites turbinata* Billings were found.

The following list of species was obtained from the lowest beds in this section:

3. *Phacops rana* Green.
12. *Goniatites uniangularis* Conrad.
13. *Bactrites obliqueseptatus* var. *arkonense* Whiteaves.
19. *Tentaculites attenuatus* Hall (var.).
24. *Platyceras bucculentum.*
27. *Pl. arkonense* S. and G.
32. *Diaphorostoma lineata* (Conrad).
61. *Stropheodonta demissa* (Conrad).
64. *Pholidostrophia iowaensis* (Owen).
74. *Chonetes scitula* Hall.
87. *Leiorhynchus laura* Bill.
104. *Spirifer mucronatus* var. *arkonensis* S. and G.
111. *Cyrtina hamiltonensis* Hall.
Crinoidal joints.
163. *Hederella canadensis* (Nich.).
196. *Arthroacantha punctobrachiata* Williams.
223. *Microcyclus discus* M. and W.

The following were found in the talus, and probably came from the coral layer:

1. *Aspidychthus notabilis* Whiteaves.
3. *Phacops rana* Green.
52. *Paracyclas lyrata* (Conrad), probably from the lower shales.
79. *Rhipidomella penelope* Hall.
80. *Rhipidomella vanuxemi* Hall.
85. *Camarotœchia horsfordi* Hall.
97. *Atrypa reticularis* (Linn.).
105. *Spirifer mucronatus* var. *thedfordensis* S. and G.
112. *Cyrtina hamiltonensis* var. *recta* Hall.
118. *Athyris fultonensis* (Swallow).
148. *Polypora arkonensis* S. A. Miller.
Fistulipora sp.
206. *Ceratopora intermedia* (Nich.).
217. *Favosites digitata* Rom.
225. *Zaphrentis prolifica* Bill.
231. *Heliophyllum tenuiseptatum* Billings.
237. *Cystiphyllum vesiculosum* Goldfuss.

Discussion and Correlation

DISCUSSION

Calvin in 1888 called attention to the three-fold division of the Hamilton beds in the Thedford region. He considered the thickness of the beds accessible to observation to be 200 or 250 feet, and noted the fact that the characteristic species of each of the three divisions are restricted to it. He makes the middle or coral zone thicker than it really is, for the total thickness of this division, inclusive of the Encrinal limestone, is only a little over 5 feet in both localities where its entire thickness is shown. The characteristic corals appear to be entirely confined to these beds, occurring chiefly in the shales above the Encrinal limestone. They are often found on the talus slopes below this level, but we did not observe them above this horizon, where their place is taken by the Alcyonarian corals. Logan * mentions an exposure "on the twenty-fifth lot of the fifth range of Bosanquet," which furnished the characteristic fossils of the coral layer and which he considered as probably above those found in the third range, where he finds about 100 feet of shales overlying the Encrinal limestone. This latter section is probably the one found in Rock glen, though our measurements show less than 50 feet of shales and calcareous beds above the Encrinal limestone. It is safe to say that the outcrop of the coral zone mentioned by Logan as occurring on the twenty-fifth lot of the fifth range (which we believe to be the same as that described under Section B, though we have no map to verify this) is not above the Rock Glen beds, but is equivalent to the Encrinal limestone and the coral-bearing shales immediately above, both of which are near the middle of the Rock Glen section.

Our measurements at Rock glen give a trifle less than 38 feet of shales above the Encrinal limestone, succeeded by about 9 feet of calcareous beds. There may be other beds above these calcareous ones which we have taken no account of, and thus the total thickness of the Upper Hamilton beds exposed on the Rivière aux Sables and its tributaries may be 102 feet, as given by Logan.

In the Rock Glen section we found the coral layer (bed 3) 3¼ feet thick, resting directly on the Encrinal limestone. At Bartlett's mills (bed 3) it has the same thickness and position. At the Brickyard (Section C, bed 3) only 2 feet are exposed, this being the highest bed shown here. The thickness of the coral layer at Section B could not be ascertained, but it holds the same relation to the Encrinal limestone as at the other localities. It is not exposed at the railroad cut at Thedford (Section A), where it probably occurs at a distance of about 15 feet below the level of the railroad track.

Twenty-six and a half feet above the coral layer at Rock glen, or nearly 30 feet above the Encrinal limestone, occurs a two-foot shale bed in which *Spirifer mucronatus* var. *thedfordensis* is most abundant (8*a*). The only other exposure of this bed is in the railroad cut near the middle of Section

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* Page 385 of his 1863 report.

A, where, as nearly as can be ascertained from the overgrown character of the exposure, it has a thickness of about 4 feet. This Spirifer is by no means confined to this bed, for it is abundant in the coral layer at Section B, and at Bartlett's mills, though it is not always possible to decide what proportion of individuals may have come from the weathered beds just above, where this variety is not uncommon.

The highest bed (number 5) exposed at Bartlett's mills represents only the lower part of bed 5 of the Rock Glen section, while bed 4 is found in both localities, retaining its lithic and physiographic features.

In the Rock Glen section, about 6 feet above the bed where *Spirifer mucronatus* var. *thedfordensis* is abundant, the calcareous beds with Ceratopora begin. In the Thedford section (Section A) the interval between the Spirifer beds and the calcareous Ceratopora beds is about the same, though from the unsatisfactory character of the section precise measurement was not possible. There can be little doubt, however, that the upper calcareous beds of Section A and those of Section D are equivalent, and they have been numbered accordingly in the sections.

Beds number 7 and 8, which are recorded with a combined thickness of 10 feet at Section A, are at Section D divided into 8 feet of shale and 18 inches of argillaceous limestone. Only about 10 feet of bed 6 are exposed at Section A, while its thickness in Rock glen is 18 feet.

It thus appears that the section near Thedford station (A) represents the upper part of the Rock Glen section, stopping in the lower part of bed 6. At Section B the succession is carried downward through the Encrinal limestone. The characters of this latter rock are not well exhibited at Section B, but at Sections C, D, and E—the Brickyard, Rock glen, and Bartletts mills respectively—it is well shown. In each of these exposures there is a bed of fissile bituminous shale intercalated in the lower part of the limestone. At the Brickyard this bed is from 2 to 4 inches thick; at Rock glen it is 3 inches thick, while at Bartlett's mills it ranges up to 6 inches in thickness. This bed is generally filled with crushed specimens of Leiorhynchus.

Among the characteristic fossils of the Encrinal limestone are *Spirifer (Delthyris) sculptilis*, *Favosites turbinata*, and *Craspedophyllum archiaci*. Of these *Spirifer sculptilis* has not been found by us outside of the Encrinal limestone. *Tropidoleptus carinatus* is also represented by a single specimen from the Encrinal limestone in our collections. *Spirifer divaricata* was likewise found by us only in the Encrinal limestone; *Rhipidomella penelope* and *R. vanuxemi* also occur here.

The lower Hamilton shales (bed 1) are exposed at the Brickyard, Rock glen, and Bartlett's mills—Sections C, D, and E respectively. At the Brickyard 15 feet are exposed; at Rock glen from 21 to 25 feet, while at Bartlett's mills about 30 feet are shown. The upper portion of this series contains few fossils, in so far as we were able to judge from our brief examination. Logan (page 382) mentions in his section on the Rivière aux Sables a 4-foot bed of shale containing "*Spirifer mucronatus* and other fossils." This we have not observed. We found, however, the talus below the Encrinal limestone covered with weathered-out specimens of *Sp. mucronatus* var. *thedfordensis* fallen from the upper beds.

The most interesting portion of the lower shales is comprised within the lower 10 feet of the mass exposed at Bartlett's mills. In this portion a number of calcareous layers are found, in which the most characteristic fossil is *Spirifer mucronatus* var. *arkonensis* S. & G. For a description of this variety see below. This shell often constitutes thin beds in which scarcely any other fossil is to be found. It is entirely restricted to the lower shales (bed 1) and apparently to the lower 10 feet at Bartlett's mills. It is not found at the Brickyard, where the section is not deep enough, nor has it been observed at Rock glen.

Among the other fossils which appear to be restricted to the lower portion of this lower series are *Platyceras arkonense*, *Arthroacantha punctobrachiata*, *Tentaculites attenuatus* var., and *Bactrites obliqueseptatum* var. *arkonense.*

The following generalized section of the exposed Hamilton beds of the Thedford region is therefore derived:

9. Calcareous Ceratopora and Bryozoa beds	10.′
8. Shales with Spirifer beds at the base	8.′
7. Argillaceous limestone	1.5′
6. Blue calcareous shale	18.′
5. Calcareous shales and shaly blue limestones	6.′
4. Argillaceous limestone with Styliolina	1.5′
3. Coral layer	3.25′
2. Encrinal limestone	3.′
1. Blue shales—lower Hamilton, the lower portion with calcareous fossiliferous beds	30.′+
Total thickness exposed	81.25+

This gives us 48 feet for the upper shales and calcareous beds and 30 for the lower. We are not aware of any accurate determination of the total thickness of the Hamilton formation in Ontario. Logan (page 387) cites a well record which gives a thickness of nearly 230 feet of Hamilton shales penetrated below 60 feet of drift without reaching the Onondaga limestone beneath, and he argues from this that the total thickness must be in the neighborhood of 300 feet. If this estimate is correct, we should expect to find the greater part of this mass below the Encrinal limestone, since we find the outcrop of the black bituminous shales of the Upper Devonian at Kettle point, less than 15 miles west and but little south of the strike of the beds from Thedford. Thus the Upper Hamilton—that is, the beds above the Encrinal limestone—can not be very much thicker than the portion exposed.

CORRELATION WITH HAMILTON BEDS OF EIGHTEEN-MILE CREEK

Turning now to a comparison of the beds of Thedford with those of Eighteen-mile creek, New York, 130 miles to the east, we find that there is a close agreement in the thickness of the formation at the two localities. Well sections, according to Prof. I. P. Bishop* (1895), show the thickness of the combined Hamilton and Marcellus to be 287 feet. The thickness of the Hamilton in that region is only 76 feet, giving a thickness of 211 feet for the Marcellus.† Thirty feet of the latter contain a mingled Hamilton and Marcellus fauna, and must be considered as transitional. If this is counted with the Hamilton, we have 106 feet of that formation and 181 feet of Marcellus. A lower Hamilton fauna existed temporarily during the early Marcellus time, while the Stafford limestone was accumulating with a thickness of 8 feet.‡

The upper Hamilton (Moscow shale) of Eighteen-mile creek is 17 feet thick, and is divisible into two distinct faunas, each characterized by a Spirifer not found above or below. The upper fauna is characterized by *Spirifer tullius*, with which are associated *Ambocœlia præumbona* and *Schizobolus truncatus*, both of which are unknown in the other faunas. *Leiorhynchus multicostus* (= *L. laura*) is also abundant. This fauna is found in the upper 4 feet of the Moscow shale.

The next fauna is characterized by *Spirifer consobrinus*, and is limited to the lower 5 feet of the Moscow shale. In certain layers *Ambocœlia umbonata* is extremely abundant. Between the two faunas are 8 feet of nearly barren shales.

About 2 feet above the Encrinal limestone and within the zone of *Spirifer consobrinus*, occurs a thin coral layer to which nearly all the characteristic large rugose corals of this region are confined. Chief among these are *Heliophyllum halli* and *Cystiphyllum vesiculosum*. Favosites and Craspedophyllum have not been noted, but they occur in the Encrinal limestone, where also a few cup corals occur. *Atrypa aspera* is abundant and confined to this bed.

The Encrinal limestone is less than 2 feet thick, and is characterized by a fauna of over 60 species. Of these, 19 are so far known to be restricted to this bed, though a number of others are among the characteristic species. *Spirifer sculptilis* is not known outside of this bed in the Eighteen-mile Creek region, and *Tropidoleptus carinatus* is best represented in this bed, as is also *Rhipidomella vanuxemi* and *Rh. penelope.* In some localities *Favosites billingsi* is extremely abundant, occurring as heads often 2 feet or more in diameter. *Heliophyllum confluens* is also found here, as well as *Craspedophyllum subcæspitosum.* Among other species restricted to this bed are:

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*Structural and Economical Geology of Erie County, p. 390.

† Grabau, 1898 (3).

‡ J. M. Clarke and Elvira Wood, Bull. 49, N. Y. State Museum, 1901.

Pleurotomaria lucina Hall.
Plethomytilis oviformis (Conrad).
Goniophora modiomorphoides Grabau.
Conocardium normale Hall.
Vitulina pustulosa Hall.
Centronella impressa Hall.
Stropheodonta nacrea (Hall) (*Pholidostrophia iowaensis*) (Owen).
Spirifer granulosus (Conrad).*

A few specimens very similar to *Sp. mucronatus* var. *arkonensis* have been found.

The lower shales, 57 feet thick, are characterized by *Spirifer mucronatus*, which in the lower beds is chiefly mucronate, but higher up becomes more condensed laterally. With this species occurs the normal Hamilton fauna of New York, which is most abundantly represented in the lowest and the highest beds of this series.†

In attempting to correlate the faunas of the two localities the question of the synchrony of the Encrinal limestone of both at once arises. Calcareous beds and even beds of pure limestone are not unknown at various levels in the Hamilton strata of western New York and Ontario. We know of none, however, which have the thickness and lithic character possessed by the Encrinal limestone of western New York, which has been traced over a wide area. At Thedford the limestone thus denominated has a similar thickness and lithic composition and texture, and there is no other limestone bed with which it can be compared. There are other beds of limestone, consisting, like the Encrinal, of comminuted crinoid remains, but they are always quite thin. The composition of the fauna of the Thedford Encrinal bed, so far as it has been ascertained, is, though meager, closely comparable to that of the Encrinal of western New York. In both regions *Spirifer sculptilis* is characteristic of it and is apparently restricted to it. The other species found in the Encrinal limestone of Thedford are, with the exception of *Favosites turbinata*, characteristic of the Encrinal limestone of Eighteen-mile creek. None of them have been found in any of the other calcareous layers, where, had they existed in this region at the time of their deposition, they ought naturally to have occurred. Thus we believe it is not a true statement of the case to say that these species are merely facies markers, and that a limestone bed occurring at any level would be characterized by them. Furthermore, the Encrinal limestone in both regions marks the period when the corals *Heliophyllum halli* and *Cystiphyllum vesiculosum*, as well as the Favositids, made their first appearance. These, in the Thedford region, are most abundant in the coral layer just above the limestone, while in western New York the Favositids characterize the Encrinal limestone and the Cyathophylloid corals the coral layer above it.

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* For a complete account of these faunas, see Grabau, 1898.

† Grabau, 1898.

Sixty miles east of Eighteen-mile creek, in the Genesee valley, the Encrinal limestone has the same lithic and faunal characters, and the characteristic corals occur 5 feet above it.* One hundred and twenty feet higher up in the same section is another calcareous layer, but poor in fossils, and a short distance above this corals are again common. Ten feet higher another limestone bed with corals occurs.

Although we have in the Genesee section a repetition of limestone beds and coral zones, we believe that the lowest of these is the equivalent of the Encrinal of western New York, for it is the only one which agrees with it faunally. We furthermore believe that the bed designated as the Encrinal limestone in the Thedford region is the stratigraphic equivalent of the bed known in New York by the same name. We believe that the facts warrant the assumption that the bed thus designated could, if exposures were sufficiently numerous, be traced with little or no interruption from the Genesee valley to Thedford and beyond.

If we accept the stratigraphic equivalency of the bed in question we are enabled to make comparisons between the lower and upper beds of the Thedford and Eighteen-mile Creek regions. As far as we can judge from our collections, the lower beds of Eighteen-mile creek are richer in species than the corresponding ones at Thedford. In both cases, however, the characteristic Spirifer is a variety of *S. mucronatus*, which has not departed far from the primitive mucronate type which was the radicle of the group of varieties classed under this name. In the Eighteen-mile Creek region the mucronate type occurs, though chiefly in the lower beds. A modified form, which resulted through an increase in height, with but a moderate increase in width, still retaining the characteristic plicated sinus and impressed fold, takes its place in the upper beds. In the Thedford region, on the other hand, the primitive characters were retained longer, thus producing a wide, much plicated form, as discussed below. This species retains the mucronate character until it is near the adult stage, when the characteristic change in growth appears. We might from this perhaps expect to find the normal form of *S. mucronatus*, which never passes beyond the mucronate stage, in the lowest beds of the Thedford region, but unfortunately these are not exposed in this locality.

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* Clarke and Luther: Livonia salt shaft.

Whether or not any portion of these lower beds carries the characteristic Marcellus fauna of New York is, of course, not known. Logan (page 385) mentions a bed of black shales holding *Stropheodonta inequistriata*, *Atrypa reticularis*, and Chonetes in the bottom of a ravine at Austin's mill. These beds he states to be 50 or 60 feet below the Encrinal limestone, and suggests that they "may possibly indicate the passage which occurs in New York between the Marcellus and Hamilton shales."

The abrupt cessation of the long-winged *Spirifer mucronatus* and the equally abrupt appearance of the short-winged variety suggests that the former became extinct or was driven out from this region, while the latter immigrated from some other locality, where it had developed. In this connection the occurrence of a few specimens of the variety arkonensis in the Encrinal limestone of western New York is interesting.*

So far as has yet been determined, *Spirifer sculptilis* is confined to the Encrinal limestone of western New York and Canada, though in the Genesee valley it occurs above the Encrinal limestone.

The order of appearance of the diagnostic Spirifers is, so far as is at present known, as follows:

Thedford Region.	*Western New York Region.*
1. ? *S. mucronatus* (radicle) ? (mucronate) not found.	1′. *S. mucronatus* (radicle) (mucronate).
2. *S. mucronatus arkonensis* (long-winged, non-mucronate).	2′. *S. mucronatus* (short-winged, high, non-mucronate).
3. *S. sculptilis.*	3′. { *S. sculptilis.* *S. mucronatus arkonensis.*
4. { *a.* *S. mucronatus thedfordensis.* *b.* *S. consobrinus.*	4′. *S. consobrinus.*
	5′. *S. tullius.*

The occurrence of *S. consobrinus* in the Thedford fauna is noted by Schuchert, who refers it to the "middle third." This undoubtedly is the coral layer.

As far as our study of the Thedford fauna throws any light on the question of the direction of migration of the Hamilton faunas within the intercontinental Hamilton sea, a general eastward migration seems to be indicated. There appear to be exceptions to this, however. One of these is *S. mucronatus thedfordensis*, which is most naturally derived from the short-winged and high variety of *S. mucronatus*, characterizing the upper Lower Hamilton of western New York. Again, *Tropidoleptus carinatus* is represented in our collections by a single specimen from the Encrinal limestone of the Thedford region. Whiteaves mentions collecting at Thedford a few specimens without stating the precise horizon. The species is common in and just below the Encrinal limestone of western New York, and is also found in the lowest true Hamilton beds of that region. On the other hand, it is unknown below the Encrinal in the Genesee valley, but common above it. This indicates an eastward migration.* It is not impossible that the species exists in beds below those exposed at Thedford.

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* Grabau, 1898.

NOTES ON SOME OF THE HAMILTON SPECIES FROM THEDFORD AND VICINITY

CERATOPORA INTERMEDIA (NICHOLSON) AND C. NOBILIS (NICHOLSON)

An examination of sections and silicified specimens of Nicholson's *Syringopora intermedia* from the type locality at Thedford proves this to belong to the genus Ceratopora defined by Grabau in 1899. A larger species of the same genus occurring with this, but in less abundance, has been identified with Nicholson's *Syringopora nobilis.*

These corals characterize the upper calcareous beds of the exposed sections at Thedford and Rock glen, where they are not infrequently silicified. *C. intermedia* also occurs in the coral layer.

HELIOPHYLLUM HALLI E. AND H.

In his recent monograph on the corals of Ontario, Lambe refers the species of Heliophyllum to Cyathophyllum, discontinuing the genus.† He gives no reason for this, and we can only gather that he does not consider the presence of carinæ a sufficient characteristic for generic differentiation.

A number of sections of characteristic specimens of *Heliophyllum halli* E. and H. from the coral layer of Thedford and vicinity have shown that in its young stages *H. halli* has the characters of a Cyathophyllum, the septa being without carinæ. The age of appearance of carinæ varies in different individuals, according to the degree of acceleration which they have experienced in their development. A cross-section of a young individual, measuring 30 millimeters across the calyx, and well supplied with carinæ, was made about 12 millimeters below the calyx, where the diameter was from 12 to 15 millimeters. It shows no carinæ whatever. The principal septa unite near the center, and the interseptal loculi are well supplied with dissepiments, indicating vesicular tissue. The specimen is a rapidly expanding one, and the number of carinæ on each septum in the calyx is 10 or more, decreasing in strength toward the center.

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* Grabau (1), 1898, p. 329.

† Contributions to Canadian Paleontology, sec. 4, pt. ii, 1901.

Another young individual, in which the carinæ are weakly developed in a calyx about 25 millimeters in diameter, was sectioned about 20 millimeters below the calyx. The greatest diameter of the section is 9 millimeters; carinæ are absent, though in a few septa slight thickenings near the margin indicate the beginning of these carinæ.

A cylindrical specimen, also young, has a diameter of about 20 millimeters at the calyx, and the septa supplied with carinæ in the outer zone, the central area of 10 millimeters diameter being free from them. The fossula is well developed. A section of the early stage with the greatest diameter of 12 millimeters shows a single well developed carina on each septum just within the peripheral margin, and on some of the septa another carina within this, or a slight thickening marking the beginning of a second carina. The four primary septa join in the center. Another section 23 millimeters in diameter shows the peripheral zone supplied with 4 or more rows of carinæ and a few weaker ones nearer the center.

A more accelerated individual shows in a section 13 millimeters in greatest diameter as many as 7 carinæ on the septum, the strength decreasing toward the center, while another of the same diameter shows only 2 or 3 carinæ on each of the larger septa.

It thus appears that in individuals which are highly accelerated the carinæ appear early in life, while in others they appear late. In some individuals, which are but little removed from the ancestral Cyathophyllum, the carinæ may not appear until the adult stage is reached. This gives us a basis for specific differentiation. *H. halli* is accelerated, the carinæ appearing early. The more primitive types should be separated specifically from this species. Now, instead of deriving an argument for generic union from this evident relationship, we have a good basis for generic separation. Beyond question, Heliophyllum as represented by *H. halli* has been derived from Cyathophyllum, for in its youthful stages it still retains the characters found in the adult of typical Cyathophyllum, such as *C. helianthoides* Goldfuss; but it has passed beyond the Cyathophyllum stage and acquired new characters in the carinæ, and therefore in any refined phylogenetic classification is entitled to generic rank.

LEIORHYNCHUS MULTICOSTUS HALL, L. LAURA BILLINGS, AND L. HURONENSIS NICHOLSON

A number of well preserved specimens of Leiorhynchus were obtained from a calcareous bed above the Encrinal limestone, but the exact position of which has not been ascertained. The plications on these shells are in general less prominent than in the figure of *L. laura* given by Billings (1860), the young being entirely free from either plications or fold and sinus. In the adult the number of plications is sometimes as high as five on either side of the sinus in the pedicle valve, but is generally much less. The sinus bears a variable number of plications, four being frequent, but as many as six faint and irregular ones have been found. On the other hand, three or in rare cases two or one (?) occur. New plications generally appear in the adult portions of the shell by bifurcation of the existing ones, or sometimes by intercalation of new ones. Those individuals in which a large number of plications exist in the adult stage may be considered as more accelerated than those in which the number remains smaller. The number of plications on the fold is in general proportional to that in the sinus. In what appears to be the least accelerated shell found, one strong plication occupies the center of the sinus, and corresponding to it there is one deep depression in the fold. On one side of this central plication a minor one occurs and reaches about two-thirds to the beak. On the other side the corresponding plication has just appeared near the front of the sinus. The shell in this case is an adult. A somewhat more accelerated individual has a strong central plication with a minor lateral plication on each side, the lateral ones not reaching as far as the central one.

Nicholson and Schuchert consider *R. laura* Billings and *R. multicostus* Hall synonymous, while Hall and Clarke * consider them distinct. These authors figure a specimen of the pauciplicate form above described as *R. laura*, but a reference to Billings' figure shows that he used a multiplicate form as the type of his species. This type occurs abundantly in a crushed condition in the bituminous shales, intercalated in the Encrinal limestone. The plications extend nearly to the beak, and, as far as can be judged, the shell is proportionally broader than that of the limestones. This variety is identical with the New York species, and appears to be the one described by Billings, thus having priority over *L. multicostus.*

The shell from the calcareous layers above described and figured by Hall and Clarke as *L. laura* we believe to be identical with *L. huronensis* Nicholson.† The figured individual is more elongate proportionally than the majority of our specimens, while the width is the same. The young of these shells are all proportionally wider than the adult, being in one stage wider than high, while in the adult the proportion of width to length is about 9 to 10 or even relatively narrower. The proportional increase of width to length in adult and old age individuals is slight and augments the thickness of the shell rather than its width. Thus an old age individual may well have an elongated form without increasing much in width, and at the same time become bulging and the beak sufficiently incurved to conceal the foramen.

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* Paleontology of New York, vol. 8.

† Paleontology of Ontario, 1874, page 90, figure 28.

While *L. laura* is chiefly restricted to the shale layers within the Encrinal limestone, a few representatives occur higher up in the upper shales. Two specimens from Thedford agree essentially with Billings' figure—the plications are numerous and continue to near the beak, and the width is approximately equal to the height. The prevailing form in the upper beds appears to be *L. huronensis*, which might be considered as a passage form to the pauciplicate Upper Devonian species.

SPIRIFER MUCRONATUS VAR. ARKONENSIS VAR. NOV.

This well marked variety characterizes the lowest beds exposed at Bartlett's mills. It is extremely elongated laterally, reaching a width ranging to 70 or 75 millimeters, with a corresponding height of 15 to 18 millimeters. A typical individual measures 63 millimeters in width by 14 millimeters in height. Another measured 56 or 58 millimeters in width by 16 in height. The wings, though much attenuated, are not mucronate in the adult stage, but the frontal margin forms a straight line from the fold or sinus to the extremity. The umbonal portion of the pedicle valve is but slightly elevated above the hinge line. The hinge area in some of the larger specimens has a height of from 2 to 2½ millimeters at the delthyrium, but gradually narrows toward the extremities. The hinge line of the brachial valve is linear, and extends the entire width of the shell. The median fold invariably bears a depression, which is often quite strongly marked, and in rare instances is only a flattening. Corresponding to this is a more or less strongly marked median plication in the sinus, though at times this is merely indicated by a slight emargination of the lines of growth. The plications are numerous and strong, decreasing very gently in width toward the lateral extremities. In the adult there are 30 or more on each side of the fold and sinus. They are rounded at the summit, and are separated by narrower interspaces. Concentric lines of growth are quite strongly marked, and are somewhat inequally distant, and generally most pronounced in the interspaces. Toward the cardinal line all the plications become obsolete, except those margining the fold and sinus. The non-plicate portion along the hinge line is generally marked by fine longitudinal striæ, which are very numerous and somewhat irregular. The cardinal process is strongly and regularly striated. The median septum of the brachial valve is moderately developed, and a faint septum occurs in the pedicle valve.

In tracing out the successive stages in the development of this variety by means of the growth lines, it becomes apparent that in the stage immediately preceding the adult stage, individuals of this variety are strongly mucronate; this mucronation becoming obsolete only by the addition of later lamellæ in the adult stage. At a still earlier stage the mucronation does not exist, the shell terminating in regular acute angles, and still earlier in right or rarely obtuse angles. In the earliest stage observed, the shell appears to have been striate, in addition to the few plications, but these striæ are seldom well preserved. In a few cases in individuals which have almost the size of the adult, the mucronate character of the earlier stage persists, this being due to a retarded development. In these therefore the more primitive features are retained throughout the life of the individual, which thus never passes beyond the normal characters of the primitive type. Such primitive forms characterize the lower Hamilton shales of northeastern Michigan, these never acquiring the elongate, non-mucronate, and multiplicate stage characteristic of the variety arkonensis.

Throughout the Hamilton strata of New York individuals occur which are mucronate in their adult stage ; these when not primitive, as is probably the case with those in the lower strata, are examples of a retarded development, the retardation affecting the individual or group of individuals (placed, perhaps, under unfavorable conditions) and not the species.

*SPIRIFER MUCRONATUS VAR. THEDFORDENSIS VAR. NOV.**

This variety is characteristic of the upper beds of the Hamilton group in the Thedford region, being entirely unknown below the Encrinal limestone. It is more than a local mutation, for it represents a distinct and decided advance in development of the typical form of that species. This is shown by a study of its development, for the shell passes through a series of transformations, which include a stage in which the immature shell has all the characters of an adult form of the primitive *S. mucronatus.* As in all varieties of this species, the earlier (nepionic) stage is non-mucronate and with a few plications only. At a comparatively early stage the mucronations appear, increasing in strength until, in the adolescent (neanic) stage, the shell is extremely mucronate and the fold of the brachial valve has a distinct median depression, while the flattening or emargination in the lines of growth in the median sinus of the pedicel valve indicates the persistence during this stage of the median plication characteristic of the primitive *S. mucronatus.*

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* Although this name is frequently used by collectors and students, we have been unable to find it in print anywhere.

While in variety *arkonensis* of the lower beds this condition persists for a long time, thus producing the elongated form, in var. *thedfordensis* the mucronate stage is comparatively short. After a certain time the shell no longer increases in width to an appreciable amount, but addition is chiefly made to the front, so that the frontal margin on either side of the center changes from a concave to a straight and finally convex outline, the shell at the same time increasing in height and convexity. Since the additions are all made to the anterior margin, no new plications appear, the number being about the same as that found on the young of variety *arkonensis* of the same width or somewhat less. With the disappearance of the mucronations in the young of variety *thedfordensis*, the depression in the fold and incipient plication in the sinus also disappear; the shell becomes extremely robust, the fold and sinus as well as plications and concentric lamellæ becoming strongly pronounced. This, together with the unusual abundance of this variety in these upper beds, indicates that the species had become well adapted to its environment. Even within this variety there is considerable variation; this in one case is due to extreme acceleration which produces a transversely short and thick-set form, the mucronate stage having been passed through rapidly and the number of plications as a result being small. On the other hand, a retarded development would cause a prolonged mucronate stage which gives the shell an extended character with acute, or in some cases of extreme retardation, slightly mucronate extremities. In these extended individuals the number of plications on either side of the fold or sinus ranges from 15 to 20, while, on the other hand, in the short-winged forms the number is not over 10 and sometimes even less. In the long-winged varieties the flattening or median depression of the fold is generally somewhat longer retained than in the short-winged ones, as might be expected. Occasionally the mucronate stage becomes extremely condensed, through acceleration in development, so as to be almost entirely eliminated; no specimen, however, in which this stage was altogether eliminated has been observed. A few specimens showing old age features have been found; in these new lamellæ have been added, which, however, scarcely extend beyond the frontal margin of the adult. Thus no further increase in height is effected, but a great thickening of the anterior margin, marked by numerous lamellæ, is produced. In the New York Hamilton an accelerated variety of *Spirifer mucronatus*, which simulates in form the Thedford species, is very common; in this the early stages are very similar to the Thedford variety, but the plicated sinus and sinuate fold are in general retained throughout, thus indicating a less degree of acceleration. The New York variety, too, is less robust, and the concentric lamellæ are less strongly marked and less regular.

In the interior of the pedicle valve is usually found a faint median septum which divides the muscular area; this, though not so strong as that of *Sp. consobrinus*, is nevertheless of the same type, and appears to mark the relationship between that species and the variety *thedfordensis*.

In the following table measurements of three stages in development of this variety—that is, the early or *nepionic*,* the youthful or *neanic*, and the adult or *ephebic*—are given, the actual height and width being first considered and after that the proportional width, the height being taken as unity. The nepionic is considered to be the stage when the shell is non-mucronate, the measurement being taken at the last line of growth preceding the mucronation. The neanic stage is the mucronate stage, the measurements being made at the stage of extreme mucronation. The ephebic is the measurement of the adult.

The average proportional width of the adult ranges from 1.5 to 2. A few individuals fall below that, and these represent extreme acceleration. They are numbers 19, 22, 30, and 56. Number 19 is the most accelerated of these, the proportional width of the adult being 1.2, while that of the neanic is as low as 1.96, showing that the adult characters were early acquired, the mucronate stage being relatively short. The specimen is a short, rotund individual.

Examples of unusual retardation are found in numbers 2, 6, 7, 10, 16, 17, 38, 49, 50, and 59, or in all those in which the proportional width is above 2. Eliminating both accelerated and retarded individuals, we get an average proportional width for the remaining of 1.85. Number 16, with a proportional width of 2.51, and number 38, with a proportional width of 2.4, represent extremes of retardation. They are comparable to accelerated individuals of the normal *S. mucronatus*. Their extremities are extremely acute, but not mucronate. Number 14 is a young individual.

From an inspection of the tables it appears that the average proportional width for the neanic stage ranges from 3.2 to 4.2, nearly 75 per cent falling within this limit. Of these the average proportional width is 3.8. The following thirteen are strongly accelerated in this stage: Numbers 5, 12, 15, 19, 22, 28, 30, 36, 39, 43, 47, 55, and 56. Of these number 19 is the most accelerated, as already noted, having a proportional width of only 1.96 in this stage. Examples of unusual retardation in this stage are seen in numbers 9, 18, 26, 48, and 57. Of these number 18 is the most retarded, with a proportional width of 4.9, and numbers 48 and 57 are next, with a proportional width of 4.7 each. The average proportional width of 6 normal adult *S. mucronatus* from Michigan was

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* For this terminology see papers by Hyatt, Jackson, Beecher, and others.

2.9, though rising as high as 3.2 and falling as low as 2.6. The average proportional width of 9 individuals of *S. mucronatus* var. *arkonensis* was found to be 3.9, though rising as high as 4.5 and falling as low as 3.5. It thus appears that the average neanic *S. mucronatus thedfordensis* is more extended proportionally than adult *S. mucronatus*, plainly approaching the adult of *S. mucronatus arkonensis*. The adults of the three varieties stand as follows: *S. mucronatus thedfordensis*, 1 : 1.85; *S. mucronatus*, 1 : 2.9, and *S. mucronatus arkonensis*, 1 : 3.9.

The following table shows the actual width and height, proportional width, and number of plications in each of three principal stages of development in *Spirifer mucronatus* var. *thedfordensis* S. and G.:

Specimen number.	EPHEBIC.				NEANIC.				NEPIONIC.			
	Width.	Height.	Proportion of width to height.	Number of plications.	Width.	Height.	Proportion of width to height.	Number of plications.	Width.	Height.	Proportion of width to height.	Number of plications.
1	39.	20.5	1.9	13	34.6	9.7	3.57	13	8.	4.5	1.77	6
2	41.	20.	2.05	12	37.5	9.2	4.07	11	8.8	3.	2.90	8
3	37.	20.5	1.80	14	34.	10.	3.40	12	7.8	3.8	2.05	8
4	37.5	19.2	1.95	14	33.3	9.7	3.43	10	4.1	2.7	1.51	6
5	31.	18.2	1.70	13	28.	9.8	2.86	12	10.	5.	2.	8
6	40.	18.8	2.13	12	38.	9.1	4.17	9	10.2	4.4	2.30	6
7	35.8	16.8	2.13	12	34.	10.	3.40	11	11.8	6.7	1.76	7
8	38.5	20.	1.93	14	34.	9.6	3.54	10	8.	4.1	1.95	6
9	32.2	16.5	1.84	12	28.6	6.6	4.33	9	8.3	4.5	1.85	7
10	38.	16.2	2.35	14	35.6	8.9	4.	11	7.4	3.3	2.24	8
11	22.3	14.8	1.50	11	30.	8.2	3.66	10	5.	2.9	1.72	4
12	39.2	19.6	2.	12	35.7	11.	3.25	9	9.	4.6	1.95	6
13	32.4	18.9	1.71	9	29.2	8.3	3.57	9	6.	3.6	1.60	5
14	35.2	21.2	1.70	11	33.	9.5	3.47	7	8.	5.6	1.40	6
15	28.	18.2	1.54	12	26.	8.9	2.92	9	8.4	4.6	1.83	6
16	46.	18.3	2.51	18	42.4	11.	3.85	14	7.4	3.7	2.	6
17	39.	18.1	2.15	13	36.4	9.8	3.71	13	4.	2.4	1.66	5
18	30.2	18.	1.69	11	36.4	7.4	4.90	10	7.	3.5	2.	6
19	22.8	18.8	1.21	9	20.8	10.6	1.96	9	7.2	4.4	1.63	8
20	34.4	18.8	1.83	11	30.	8.5	3.53	11	8.4	4.	2.10	8
21	26.4	17.6	1.50	11	22.4	6.2	3.61	9	9.	4.2	2.14	7
22	28.	20.	1.40	9	24.2	7.2	3.36	10	6.6	3.2	2.06	5
23	40.	21.4	1.9	11	36.6	10.5	3.5	8	5.2	3.1	1.7	5
24	43.	21.3	2.	15	39.2	10.9	3.6	12	7.4	3.7	2.	5
25	38.	22.4	1.70	12	35.6	9.	3.9	9	5.8	3.6	1.6	5
26	38.	18.4	2.06	11	35.	8.1	4.3	11	5.2	2.9	1.8	6
27	42.	20.	2.	12	39.	11.5	3.4	11	8.	4.	2.	7
28	36.2	19.7	1.80	12	34.	11.8	2.9	11	11.2	5.5	2.	8
29	33.	20.	1.60	12	28.2	8.	3.5	8	8.2	4.3	1.9	6

Specimen number.	Ephebic.				Neanic.				Nepionic.			
	Width.	Height.	Proportion of width to height.	Number of plications.	Width.	Height.	Proportion of width to height.	Number of plications.	Width.	Height.	Proportion of width to height.	Number of plications.
30	28.	19.6	1.43	10	22.4	10.4	2.2	9	13.	6.1	2.1	8
31	34.8	17.3	2.	12	32.	9.	3.5	10	7.4	3.7	2.	7
32	37.8	20.5	1.8	13	33.2	9.2	3.6	9	5.	2.9	1.7	5
33	41.6	22.	1.9	14	39.	9.3	4.2	11	4.2	2.8	1.5	7
34	39.	20.	1.95	13	37.2	9.9	3.76	10	10.	5.	2.	8
35	33.4	20.1	1.7	12	28.8	7.7	3.8	10	6.4	3.9	1.6	6
36	32.6	17.6	1.9	10	18.	6.6	2.7	8	6.4	4.	1.6	5
37	40.4	20.8	1.9	12	39.	9.4	4.1	9	10.	4.4	2.3	7
38	41.8	17.8	2.4	16	36.4	9.5	3.8	10	5.6	3.4	1.6	7
39	35.6	18.9	1.9	10	34.	12.1	2.8	11	6.4	3.3	1.9	7
40	34.	16.8	2.	11	31.	7.8	3.9	11	6.6	3.6	1.8	5
41	37.8	14.	2.7	14	35.8	9.6	3.7	12	7.6	3.3	2.3	6
42	32.6	17.7	1.8	11	28.4	7.3	3.8	9	6.6	3.9	1.7	7
43	32.	18.6	1.7	11	26.2	10.5	2.5	9	7.	4.1	1.7	7
44	26.6	16.4	1.6	12	21.	6.2	3.4	10	5.6	3.8	1.5	5
45	34.8	17.4	2.	12	30.4	8.9	3.4	12	5.6	3.7	1.5	6
46	36.2	20.	1.8	13	31.2	8.8	3.5	13	7.	3.5	2.	7
47	36.8	19.	1.9	11	32.6	12.7	2.6	11	6.	3.5	1.7	7
48	37.	20.	1.8	13	32.4	6.9	4.7	11	7.	3.5	2.	6
49	38.	17.2	2.2	15	32.	9.5	3.4	10	12.	6.1	2.	9
50	41.2	19.3	2.1	12	39.2	10.	3.9	11	6.8	3.6	1.9	6
51	38.2	20.3	1.9	12	33.4	8.9	3.8	11	5.6	3.2	1.8	6
52	32.6	19.2	1.7	11	28.	6.9	4.	11	5.	3.1	1.6	5
53	29.4	19.2	1.5	11	27.	7.5	3.6	11	8.	4.	2.	7
54	35.	20.	1.8	11	33.6	8.8	3.8	10	7.4	3.8	1.9	8
55	30.	19.8	1.5	14	27.8	9.5	2.9	9	7.8	4.7	1.7	6
56	26.4	19.2	1.4	9	21.6	10.6	2.	8	8.	4.5	1.8	6
57	42.	21.	2.	13	39.2	8.2	4.7	7	5.8	4.	1.5	7
58	36.4	19.8	1.8	15	33.	9.6	3.4	14	7.	3.5	2.	7
59	41.	18.5	2.2	13	39.	10.8	3.6	13	9.4	4.8	1.8	6

This variety is already well developed in the coral layer, where characteristic individuals occur. In this horizon the variation is perhaps somewhat greater than in the higher ones, if our collections adequately represent this feature. Along with normal individuals of variety *thedfordensis* occur others, which retain the primitive *mucronatus* character for a sufficiently long period to permit their being classed under that species. These individuals are more elongate than the normal form of the variety *thedfordensis*, but they never reach the extreme elongation characteristic of variety *arkonensis*. The plicated sinus and medially depressed or flattened fold are also retained for a long time. These individuals of the coral layer therefore represent the connecting forms between the typical *S. mucronatus* and the shortened variety *thedfordensis.*

PLATYCERAS ARKONENSE VAR. NOV.[*]

The above name is proposed for the small spiny species of Platyceras which characterizes the lower beds of the Hamilton group at Bartlett's mills and which has generally been considered identical with Hall's *P. dumosum rarispinum* of the Onondaga beds.

This species is characterized by its closely incurved apex, which has the features of the young Diaphorostoma, and may be referred to as the Diaphorostoma stage. It comprises about two volutions, the last of which, however, expands much more rapidly than the corresponding one in Diaphorostoma. The lines of growth in the early stage are perfectly regular, and in most cases spines do not appear until the Diaphorostoma stage is past. A small specimen, having the form and degree of coiling of this species, but without spines, was found in the lowest bed at Bartlett's mills. What may be considered the adult portion of the whorl is broadly expanded, the aperture varies from oval to irregularly rounded, with a diameter sometimes exceeding 20 millimeters. The surface of the adult portion of the shell is furnished with tubular spines, which in some specimens have been found to have a length of 8.5 millimeters, not counting the apex, which was broken off, and would have given a total length of perhaps 10 millimeters. The lines of growth on the adult portion of the shell are somewhat sinuous, though no pronounced emargination has been observed in any of the specimens.

The characteristic features of this species are the closely and regularly incoiled beak (Diaphorostoma stage), and regularly, though rapidly, expanding adult portion of the shell with its strongly marked spines. The differences between this and the typical rarispinum from the Onondaga limestone will be apparent on the inspection of the figures given by Hall.[†] The largest adult specimens of this species observed are about 25 millimeters in length, though old-age individuals of much larger size occur, as noted beyond. From the abundance of this species and its uniform size and characters, we must assume that these specimens represent the normal adult characteristics, and that they are not young individuals of a type which normally is of a larger size.

A large individual, something over 40 millimeters in length, and the aperture, which is subquadrate, about 30 millimeters in diameter, has been found in the coral layer of the same locality—that is, 28 to 30 feet above the bed in which the normal representatives of this species occur. In form this is identical with the smaller typical species, representing merely a continuous and regular enlargement until it is more than twice the size of the normal individual. The number of spines found on the surface of this shell is proportional to the size, and they are scattered over the whole surface. This shell therefore is merely an extremely large individual of this species, developed under favorable conditions, and we do not believe that it is conspecific with rarispinum of the Onondaga horizon.

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[*] 1874, *Platyceras dumosum* var. *rarispinosum* Hall (?) Nicholson; Paleontology of Ontario, page 117, figure 52.

[†] Paleontology of New York, vol. v, pt. 2.

*PLATYCERAS SUBSPINOSUM HALL**

In the coral layer at Sections C and E were found specimens which have all the appearance of senescent (gerontic) individuals of *P. arkonense*. The specimen from the brickyard, Section C, is somewhat crushed, but has a length of over 40 millimeters. The young shell, up to a transverse diameter of 8 or 10 millimeters, has all the characteristics of *P. arkonense*, as found in the lowest beds at Bartlett's mills, except that the spines are somewhat more numerous and crowded. The number of volutions in the young corresponds closely to that found in the lower beds. The transverse lines of growth are as strongly marked, or more so, than in that species, and in addition to these we find fine, regular, revolving lines subequidistant, and most noticeable between the strong lines of growth. On certain portions of the shell the lines of growth and the revolving lines are equal in strength, thus giving a cancellated appearance to the surface similar to that found on the shell of *Diaphorostoma lineata*. In fact, except for the spines, the first 2½ volutions are identical with the young *Diaphorostoma lineata* both in form and ornamentation. The revolving striæ have also been noticed on some typical specimens of *P. arkonense* from the lower beds.

Beyond this point the shell expands, though less rapidly than in the individual before noted. The spines become few and far between ; the lines of growth assume a strongly wavy appearance, indicating a sinuous margin, and this becomes most strongly pronounced in a somewhat later stage, where, a little to the right of the dorsum, a deep marginal notch is indicated by the abruptly backward deflected lines of growth. On the opposite side the lines of growth are strongly wavy, but no pronounced sinuation is formed. The last 10 or 15 millimeters of the shell are without the emargination, and the lines of growth in general are less sinuous, becoming almost straight at the aperture. In the portion of the shell immediately succeeding the spiny stage the revolving lines are well marked. These gradually become obsolete toward the front, where also the spines have almost disappeared. This last portion of the shell compares well with *P. thetis* var. *subspinosum*, as figured by Hall, except that the strongly marked notch is not shown in that specimen.

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* Compare *Platyceras thetis* var. *subspinosum* Hall. Paleontology of New York, vol. v, pt. 1, plate 3, figure 30.

The specimen from the coral layer of Bartlett's mills has the original form well preserved. Its earliest stages are strongly spinous, even in the Diaphorostoma stage, showing thus a high degree of acceleration. The spines on the surface of the later stages are more numerous than is the case with the specimens from Section C. The strong emargination to the right of the dorsum is well marked in the adolescent (neanic) stage of this specimen, but finally becomes obliterated. The margin of the adult stage is gently sinuous. Where the surface is well preserved, the revolving lines of growth are visible in the adolescent stage, and there are faint indications of them in the adult stage.

A similar specimen from Eighteen-mile creek, apparently from the Encrinal limestone, occurs in the collection of the geological department of Columbia university. The apex of this specimen is somewhat less enrolled than in those from Thedford, and the spines are fewer in number and most abundant on the young shell. The lines of growth have a similar wavy character, and the sinuation, though less pronounced, occurs to the right of the dorsum. Owing to the somewhat imperfect preservation, it is impossible to say whether the revolving lines existed on this specimen. Nevertheless, there are faint indications of them.

In identifying these shells with Hall's *P. thetis* var. *subspinosum* from Canandaigua lake, we propose to raise this to specific rank, since we do not believe that this form has been derived from *P. thetis*. In fact, as already noted, the derivation from *P. arkonense* is clear, and the direct derivation of both from *Diaphorostoma lineata* (Conrad) is not improbable in spite of the existence of spines in the "Platyceræ."

In this connection some Devonian Platyceræ from Iowa are suggestive. A young shell has the general form of the typical *P. arkonense*, except that the last whorl enlarges somewhat more rapidly. The spines are very few and are restricted to the dorsum. The lines of growth near the aperture are wavy, there being a few faint longitudinal plications. Some of the larger specimens associated with this show a series of longitudinal plications similar to those of *P. thetis*, but the apex is more enrolled and the aperture is more oblique. The spines have become obsolete.

With this occurs associated a perfect, regularly coiled, non-spinous individual with regular lines of growth and in form a typical Diaphorostoma, except for the rapid enlargement of the body whorl. That Diaphorostoma is ancestrally related to these species of Platyceras can not be doubted, and since similar relations exist between Lower Devonian Diaphorostoma and Platyceras, the question arises whether the so-called genus Platyceras may not be of polyphyletic origin.

PLATYCERAS THETIS HALL

The specimens referred to this species have a very short Diaphorostoma stage, and the coiled apex is free from the main body whorl. The surface is characterized by faint longitudinal folds, which are most regular on the left side of the dorsum. There is a strong sinuosity indicated by the growth lines on the dorsum or a little to the right of it. There is also a strong fold on the left lower side which produces a pronounced emargination in the peristome. The aperture makes an angle of about 45 degrees with the plane of the whorl. The specimens were found at the base of the cliff at Bartlett's mills and probably belong to the Lower Hamilton.

PLATYCERAS BUCCULENTUM HALL

In the lowest beds at Bartlett's mills a number of specimens were found having the form, obliquity of aperture, and coil of this species, but without the strongly marked fold on the right side. The apex is about as much enrolled as in *P. thetis*, and the Diaphorostoma stage is about the same length. At first the enlargement is very gentle, then it is more rapid, thus giving the upper portion of the shell a pinched appearance. The plane of the coil is nearly in line with the right margin of the peristome, almost the whole of which lies to the left of the plane drawn through the initial coil. In the largest of the specimens found the characteristic fold is slightly developed on the right side, and the lines of growth are slightly sinuous, there being an addition of several minor revolving folds. In general, however, the species as here represented is without the fold, and the peristome has a regular outline. It agrees very closely with the individual figured by Hall* from Canandaigua lake, New York, and also the specimen from the Hamilton of the Genesee valley.

PLATYCERAS QUINQUESINUATUM ULRICH

A single specimen agreeing in general with the description of this species, but more slender than those figured by Whiteaves, was found in the coral layer of Bartlett's mills.

TABLE SHOWING DISTRIBUTION OF SPECIES IN THE THEDFORD REGION

We have recorded in the table the horizon of all the species obtained by us at Thedford and vicinity, and have given as near as possible those listed by Whiteaves, but not contained in our collections. For purposes of comparison, we have also recorded the distribution of these species at Eighteen-mile creek and vicinity.

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*Paleontology of New York, vol. 5, part 2, plate 3, figure 29.

The following notation has been used:

c = common.
C = very common.
r = rare.
R = very rare.
rc = fairly common.
cf = identification only open to question.
? = horizon only open to question.
Cn = recorded by Calvin.
S = recorded by Schuchert (Whiteaves' list).
W = recorded by Whiteaves.

It will be found useful to bear in mind the following notes when consulting the table:

a. *Orthoceras exile* is found only in the Strophalosia bed at the base of the Hamilton, in the Eighteen-mile Creek region (Grabau 1).

b. *Phanerotinus laxus.* This is characteristic of the shales below the Strophalosia bed or basal Hamilton at Eighteen-mile creek (Grabau 1).

c. *Loxonema* sp. Two species are abundant in the Strophalosia bed at Eighteen-mile creek; another occurs in the Encrinal limestone, and still another in the lower shales (see Grabau 3, 1899).

d. *Nuculites triqueter.* This occurs only in the Upper Marcellus and Transition shales of the Eighteen-mile Creek region.

e. *Paracyclas lirata.* Found only in the Marcellus shales of Eighteen-mile Creek region.

f. *Stropheodonta demissa* is almost entirely restricted to the shales immediately below the Encrinal limestone at Eighteen-mile creek.

g. *Strophalosia truncata* is almost wholly confined to the Strophalosia or basal Hamilton bed at Eighteen-mile creek.

h. Many conodonts have been described from Eighteen-mile creek (see Grabau 3).

	THEDFORD REGION.						EIGHTEEN-MILE CREEK.			
	Horizon not recorded.	Lower shales, bed 1.	Encrinal, bed 2.	Coral layer, bed 3.	Upper shales, beds 4–8.	Upper limestone, bed 9.	Lower shales.	Encrinal limestone.	Moscow shales.	Notes.
PISCES:										
1. *Aspidychthys notabilis?* Whiteaves	....	?	....	....	....	....	....	....	....	....
2. *Ptyctodus calceolus* Newb. and Worth	W	....	....	....	....	....	....	....	....	....
TRILOBITA:										
3. *Phacops rana* Green	....	c	....	c	c	c	C	c	c	....
4. *Cryphæus boothi* Green	....	....	?	rc	c	c	c	r	r	....
5. *Prœtus crassimarginatus* Hall	....	S	....	....	....	....	....	....	....	....
6. *Proetus rowi* (Green)	W	....	....	....	....	....	r	..	....	....
PHYLLOPODA:										
7. *Elymocaris hindei* Jones and Woodw.	W	....	....	....	....	....	....	....	....	....

	Thedford Region.						Eighteen-Mile Creek.			
	Horizon not recorded.	Lower shales, bed 1.	Encrinal, bed 2.	Coral layer, bed 3.	Upper shales, beds 4-8.	Upper limestone, bed 9.	Lower shales.	Encrinal limestone.	Moscow shales.	Notes.
Ostracoda:										
8. *Primitiopsis punctulifera* (Hall)		c		c	C	c	r			
9. *Ulrichia conradi* Jones	W									
10. *Barychilina walcotti* Jones					R					
Cephalopoda:										
11. *Nephriticeras liratus* Hall	W									
12. *Goniatites uniangularis* Conr.		C				R	R			
13. *Bactrites arkonense* Whiteaves		C								
14. *Orthoceras anax* Bill	W									
15. *O. lambtonense* Whiteaves				cf						
16. *O. subulatum ?* Hall	W						r	R		
17. *O. exile ?* Hall	W						c			a
18. *O. arkonense* Whiteaves	W									
Pteropoda:										
19. *Tentaculites attenuatus* Hall (var.)		C				R				
20. *T. gracilistriatus* Hall					cf		C		C	
21. *Styliolina fissurella* (Hall)				?	C		C		rc	
22. *Coleoprion ? tenuis* Hall		W								
23. *Hyolithes aclis* Hall		S								
Gastropoda:										
24. *Platyceras bucculentum* Hall.		c						R		
25. *P. thetis* Hall		c					r			
26. *P. erectum* Hall	W						r			
27. *P. arkonense* S. and G.		C		R						
28. *P. subspinosum* Hall				r				R		
29. *P. carinatum* Hall	W						r	rc		
30. *P. quinquesinuatum* Ulrich				R						
31. *Orthonychia conicum* Hall				r				?		
32. *Diaphorostoma lineatum* (Conrad)		r		r			c	rc	r	
33. *D. plicatum* (Whiteaves)	W									
34. *D. shumardi* (De Vern.)	W									
35. *D. turbinatum ?* (Conrad)		S								
36. *Pleurotomaria arkonensis* Whiteaves					cf					
37. *Pl. capillaria* Hall		S					rc			
38. *Phanerotinus laxus* Hall	W						R	R		b
39. *Loxonema* sp.	W						C	r		c
Pelecypoda:										
40. *Aviculopecten princeps* (Conrad).						R	rc	r		
41. *Pterinea flabellum* (Conrad)				R	r		c			
42. *Actinopteria boydii* (Conr.)	W						r			
43. *Leiopteria rafinesqii* Hall.					S		R			
44. *Limopteria macroptera* (Conr.)				S						
45. *Cypricardella bellistriata ?* (Conr.)	W						r	R		
46. *Nucula lirata* Conr.		S								
47. *Nuculites triqueter* Conr.		S?			c		r			d
48. *Leda rostallata* Conr.	W									
49. *Paleoneilo plana* Hall		S								
50. *Nyassa arguta* Hall	W									
51. *Grammysia arcuata ?* Conr., var.	W						R			
52. *Paracyclas lirata* (Conr.)		R					R			e

	THEDFORD REGION.						EIGHTEEN-MILE CREEK.			
	Horizon not recorded.	Lower shales, bed 1.	Encrinal, bed 2.	Coral layer, bed 3.	Upper shales, beds 4–8.	Upper limestone, bed 9.	Lower shales.	Encrinal limestone.	Moscow shales.	Notes.
53. *Orthonota parvula* Hall	....	S	....	...	....	....	R	....	....	....
BRACHIOPODA:										
54. *Lingula ligea* Hall	W	....	....	....	....	....	....	....	....	....
55. *L. thedfordensis* Whiteaves	....	....	....	?	....	....	....	....	....	....
56. *Orbiculoidea doria* (Hall)	W	....	....	....	....	....	....	....	r	....
57. *Crania cranistriata* (Hall)	....	....	....	R	....	....	r	....	....	....
58. *Craniella hamiltoniæ* (Hall)	....	....	....	R	....	....	r	....	r	....
59. *Pholidops hamiltoniæ* Hall	....	....	....	R	....	....	c	....	c	....
60. *Stropheodonta concava* Hall	....	....	....	r	R	R	c	r	....	....
61. *S. demissa* (Conr.)	....	R	....	c	?	c	C	R	....	f
62. *S. inequistriata* (Conr.)	W	....	....	....	....	cf.	C	r	rc	....
63. *S. plicata* Hall	W	....	....	....	....	....	r	....	....	....
64. *Pholidostrophia iowaensis* (Owen)	....	R	....	c	r	r	c	rc	....	....
65. *Leptostrophia perplana* (Conr.)	....	....	....	r	R	R	c	rc	c	....
66. *Leptæna rhomboidalis* (Wilckins)	W	....	....	....	....	....	....	....	....	....
67. *Orthothetes anomalus* (Winchell)	....	....	....	S	....	....	....	....	....	....
68. *O. arctostriatus* Hall	....	S	....	....	cf	R	c	....	r	....
69. *O. perversus* Hall	W	....	....	....	....	r	r	....	....	....
70. *Chonetes coronata* Conrad	W	....	....	....	....	....	rc	rc	....	....
71. *Ch. lepida* Hall	....	....	....	c	c	c	C	....	rc	....
72. *Ch. lineata* Conr	....	Cn	....	....	....	....	....	....	....	....
73. *Ch. setigera* Hall	W	....	....	....	....	....	r	....	....	....
74. *Ch. scitula* Hall	....	c	....	....	r	....	C	r	r	....
75. *Ch. vicina* (Castelneau)	....	C	....	....	r	....	r	r	C	....
76. *Strophalosia radicans* (A. Winch.)	....	....	....	S	....	....	....	....	....	....
77. *St. truncata ?* (Hall)	W	....	....	....	....	....	C	....	....	g
78. *Productella productoides* (Murch.)	....	....	....	cf	....	....	....	....	....	....
79. *Rhipidomella penelope* Hall	....	?	R	c	....	....	r	c	....	....
80. *Rhipidomella vanuxemi* Hall	....	?	R	R	....	....	C	C	r	....
81. *Pentamerella pavilionensis* Hall	....	R	....	....	....	....	....	....	....	....
82. *Gypidula læviuscula* Hall	....	....	....	S	....	....	....	....	....	....
83. *Camarotœchia sappho* (Hall)	....	....	....	S	....	....	c	rc	....	....
84. *C. thedfordensis* Whiteaves	....	....	....	r	....	....	....	....	....	....
85. *C. horsfordi* (Hall)	....	....	....	?	....	....	r	r	r	....
86. *Trigeria lepida* Hall	....	....	....	r	....	....	?	....	....	....
87. *Leiorhynchus laura* (Bill.)	....	....	C	c	r	R	C	....	C	....
88. *L. huronensis* Nich	....	....	....	....	C	....	....	....	....	....
89. *L. iris* Hall	W	....	....	....	....	....	....	....	....	....
90. *Pugnax kernahani* Whiteaves	W	....	....	....	....	....	....	....	....	....
91. *Cyclorhina nobilis* Hall	....	....	....	R	....	....	....	....	....	....
92. *Eunella attenuata* Whiteaves	....	....	....	r	....	....	....	....	....	....
93. *E. harmonia* Hall	....	....	....	S	....	....	....	....	....	....
94. *E. simulator* Hall	W	....	....	....	....	....	....	....	....	....
95. *Cranæna romingeri* Hall	....	....	....	S	....	....	rc	....	....	....
96. *Tropidoleptus carinatus* Hall	....	....	R	....	....	....	c	C	....	....
97. *Atrypa reticularis* (Linn.)	....	....	....	c	....	R	c	....	c	....
98. *A. spinosa* Hall	W	....	....	....	....	....	....	....	C	....
99. *Spirifer audacula* (Conr.)	....	....	R	....	....	....	c	rc	c	....
100. *S. divaricata* Hall	....	....	R	....	....	....	....	....	....	....
101. *S. euryteines* Owen	W	....	....	....	....	....	....	....	....	....
102. *S. granulosa* (Conr.)	W	....	....	....	....	....	C	C	....	....

	Thedford Region.						Eighteen-mile Creek.			
	Horizon not recorded.	Lower shales, bed 1.	Encrinal, bed 2.	Coral layer, bed 3.	Upper shales, beds 4–8.	Upper limestone, bed 9.	Lower shales.	Encrinal limestone.	Moscow shales.	Notes.
103. *S. mucronatus* (Conrad)	....	....	....	cf	....	....	C	R	R	....
104. *S. mucronatus* var. *arkonense* S. & G.	....	C	....	....	....	....	....	R	....	....
105. *S. mucronatas* var. *thedfordense* S. & G.	....	....	....	c	C	c	....	....	....	....
106. *S. subdecussata* Whiteaves	W	....	....	....	....	....	....	....	....	....
107. *S. consobrinus* (D'Orbigny)	....	....	....	S	....	cf	....	....	c	....
108. *S. sculptilis* Hall	....	....	r	....	....	....	....	rc	....	....
109. *Reticularia fimbriata* (Conr.)	....	....	....	Cn	....	....	C	rc	....	....
110. *Martinia maia* (Bill.)	W	....	....	....	....	....	....	....	....	....
111. *Cyrtina hamiltonensis* Hall	....	R	....	rc	c	....	c	....	R	....
112. *C. hamiltonensis* var. *recta* Hall	....	?	....	....	R	....	r	....	....	....
113. *Ambocœlia umbonata* (Conr.)	....	....	....	....	c	....	C	r	C	....
114. *Nucleospira concinna* Hall	....	....	....	r	....	....	C	R	r	....
115. *Cryptonella* sp.	....	....	....	r	....	....	....	....	....	....
116. *Rhynchospira ? eugenia* (Bill.)	....	....	....	r	....	....	....	....	....	....
117. *Parazyga hirsuta* Hall	....	....	....	cf	....	....	?	....	....	....
118. *Athyris fultonensis* (Swallow)	....	?	....	c	....	c	....	....	....	....
119. *A. spiriferoides* (Eaton)	....	....	....	cf	cf	cf	C	rc	c	....
120. *Meristella barrisi* Hall	W	....	....	....	....	....	?	....	....	....
121. *M. haskinsi* Hall	W	....	....	....	....	....	....	r	....	....
122. *M. rostrata* Hall	....	....	....	....	R	....	....	R	....	....
123. *Charionella scitula* Hall	W	....	....	....	....	....	....	....	....	....
124. *Pentagonia unisulcata* Conr.	W	....	....	....	....	....	....	....	....	....
POLYZOA (BRYOZOA):										
125. *Intrapora cosciniformis* (Nich.)	W	....	....	....	....	....	....	....	....	....
126. *I. elegantula* (Hall)	....	....	....	R	....	....	....	....	....	....
127. *Coscinium striatum* Hall	W	....	....	....	....	....	....	....	....	....
128. *Cystodictya incisurata* (Hall)	....	S	....	....	....	....	C	r	....	....
129. *C. incrassata* (Hall)	W	....	....	....	....	....	....	....	....	....
130. *C. meeki* (Nichol.)	W	....	....	....	....	....	....	....	....	....
131. *C. rectilinea* (Hall)	W	....	....	....	....	....	....	....	....	....
132. *Semiopora bistigmata* Hall	W	....	....	....	....	....	....	....	....	....
133. *Tæniopora exigua* Nich.	W	....	....	....	....	....	c	....	....	....
134. *T. penniformis* Nich.	W	....	....	....	....	....	....	....	....	....
135. *Scalaripora canadensis* Whit.	W	....	....	....	....	....	....	....	....	....
136. *Semicoscinium labiatum* Hall	....	....	....	c	....	....	....	....	....	....
137. *Peleschara ?* sp.	....	....	....	....	....	R	....	....	....	....
138. *Streblotrypa hamiltonensis* (Nich.)	....	....	....	....	....	C	c	....	....	....
139. *Fenestella arkonense* Whiteaves	....	....	....	rc	....	....	....	....	....	....
140. *F. davidsoni* Nich.	W	....	....	....	....	....	....	....	....	....
141. *F. filiformis* Nich.	W	....	....	....	....	....	....	....	....	....
142. *F. nicholsoni* Whiteaves	W	....	....	....	....	....	....	....	....	....
143. *Reteporina prisca* (Nichols.)	....	....	....	c	....	....	....	....	....	....
144. *Leioclema minutissimum* (Nich.)	W	....	....	....	....	....	....	....	....	....
145. *Ptilopora striata* Hall	W	....	....	....	....	....	....	....	....	....
146. *Trematopora carinata* Hall	W	....	....	....	....	....	....	....	....	....
147. *Polypora latitruncata*	....	?	....	....	....	....	....	....	....	....
148. *Polypora arkonensis* S. A. Miller	....	?	....	....	....	....	....	....	....	....
149. *Amplexopora barrandi* (Nich.)	W	....	....	....	....	....	....	....	....	....
150. *A. moniliformis* (Nich.)	W	....	....	....	....	....	....	....	....	....
151. *Leptotrypa quadrangularis* (Nich.)	W	....	....	....	....	....	....	....	....	....
152. *Ceramopora huronensis* Nich.	W	....	....	....	....	....	....	....	....	....
153. *Fistulipora romingeri* Nich. and Ford.	W	....	....	....	....	....	....	....	....	....

	THEDFORD REGION.						EIGHTEEN-MILE CREEK.			
	Horizon not recorded.	Lower shales, bed 1.	Encrinal, bed 2.	Coral layer, bed 3.	Upper shales, beds 4–8.	Upper limestone, bed 9.	Lower shales.	Encrinal limestone.	Moscow shales.	Notes.
154. *F. subtilis* Hall	W									
155. *F. utriculus* Rominger				rc	?	C				
156. *F. variopora* (Hall)	W									
157. *T. incrassata* (Nicholson)						Cn				
158. *Lichenalia ramosa* Hall	W									
159. *L. stellata* Hall	W						r			
160. *L. subtrigona* Hall	W									
161. *Pinacotrypa elegans* (Rom.)	W									
162. *Botryllopora socialis* Nich				R			r			
163. *Hederella canadensis* (Nich.)		?			C		r			
164. *H. cirrhosa* Hall	W									
165. *H. filiformis* (Nich.)				rc	C				r	
166. *Hederella magna* Hall				S						
167. *Ascodictyon fusiforme* Nich	W									
168. *Asc. stellatum* Nich	W									
VERMES:										
169. *Spirorbis angulatus* Hall	W						c			
170. *S. arkonensis* Nich					?					
171. *S. omphalodes* Nichols				c	C					
172. *S. spinuliferus* Nich	W									
173. *Autodetus lindstrœmi* Clarke	W						r			
174. *Ortonia intermedia* Nich	W									
175. *Eunicites alveolatus* Hinde	W									h
176. *E. nanus* Hinde	W									
177. *E. palmatus* Hinde	W									
178. *E. tumidus* Hinde	W									
179. *Aenonites compactus* Hinde	W									
180. *Arabellites politus* Hinde	W									
181. *A. similis arcuatus* Hinde	W									
182. *Nereidavus solitarius* Hinde	W									
ASTEROIDEA:										
183. *Palæaster eucharis* Hall		S?								
BLASTOIDEA:										
184. *Pentremites lycorias* Hall				Cn						
185. *Pentremitidia filosa* Whit	W									
186. *Nucleocrinus elegans* Conr				r						
187. *Granatocrinus leda* (Hall)	W									
188. *Codaster canadensis* Bill	W									
189. *Eleutherocrinus cassedayi* Shumard and Yandell	W									
CRINOIDS:										
190. *Gilbertsocrinus spinigerus* (Hall)	W									
191. *Dolatocrinus canadensis* Whit	W									
192. *D. subaculeatus* Whit	W									
193. *Dolatocrinus* sp				rc						
194. *Megistocrinus rugosus* Lyon and Casseday	W									
195. *Gennæocrinus arkonensis* Whit	W									
196. *Arthroacantha punctobrachiata* Williams		c								

	Thedford Region.						Eighteen-mile Creek.			
	Horizon not recorded.	Lower shales, bed 1.	Encrinal, bed 2.	Coral layer, bed 3.	Upper shales, beds 4–8.	Upper lime-stone, bed 9.	Lower shales.	Enchinal lime-stone.	Moscow shales.	Notes.
197. *Taxocrinus lobatus* (Hall)					Cn					
198. *Botryocrinus crassus* (Whit.)	W									
199. *Ancyrocrinus bulbosus* Hall	W						r		r	
Hydroidea:										
200. *Clathrodictyon reteforme* (Nich. and Murie)	W									
201. *Stromatopora mamillata* Nich				S						
202. *Stromatoporella granulata* Nich	W									
203. *St. incrustans* Hall and Whitf	W									
Anthozoa:										
204. *Aulopora serpens* (Goldf.)				R	R		r			
205. *Monilopora antiqua* Whit				R						
206. *Ceratopora intermedia* (Nich)				c		C				
207. *C. nobilis* (Billings)						c				
208. *C. dichotoma* Grabau				R			c		c	
209. *Trachypora elegantula* Bill				c	R					
210. *T. ornata* (Rom.)	W									
211. *Cladopora fisheri* (Bill.)				c						
212. *Cl. frondosa* (Bill.)				C						
213. *Cl. ræmeri* (Bill.)				C						
214. *Striatopora linnæana* Bill				C						
215. *Alveolites goldfussi* Bill				c						
216. *Ræmeria ramosa* Whit				R						
217. *Favosites digitata* Rom				C						
218. *F. placenta* Rom				C						
219. *F. clausa* Rom				C						
220. *F. turbinata* Bill			C	c						
221. *F. billingsi* Rom				C				C		
222. *F. alpenensis* Winch				c		R				
223. *Microcyclus discus* Meek and Worth		c		Cn?						
224. *Zaphrentis cornicula* Lesueur	W									
225. *Z. prolifica* Bill				c						
226. *Cyathophyllum zenkeri* Bill				cf						
227. *Cy. conatum* Hall				C					c	
228. *Cy. robustum* Hall				cf						
229. *Heliophyllum exiguum* Bill	W									
230. *H. halli* E. and H.				C				r	c	
231. *H. tenuiseptatum* Bill				C						
232. *Craspedophyllum archiaci* (Bill.)			c					rc		
233. *C. subcæspitosum* (Nich.)				C				rc		
234. *Diphyphyllum strictum* E. and H.	W									
235. *Acervularia davidsoni* E. and H.	W									
236. *Phillipsastræa vernueili* E. and H.				S						
237. *Cystiphyllum vesiculosum* Goldf.				C					c	
238. *C. conifollis* Hall				C					C	
239. *C. superbum* Nich.	W									
Spongiæ:										
240. *Receptaculites neptuni* Defr	W									
241. *Astræospongia hamiltonensis* M. and W.				R						

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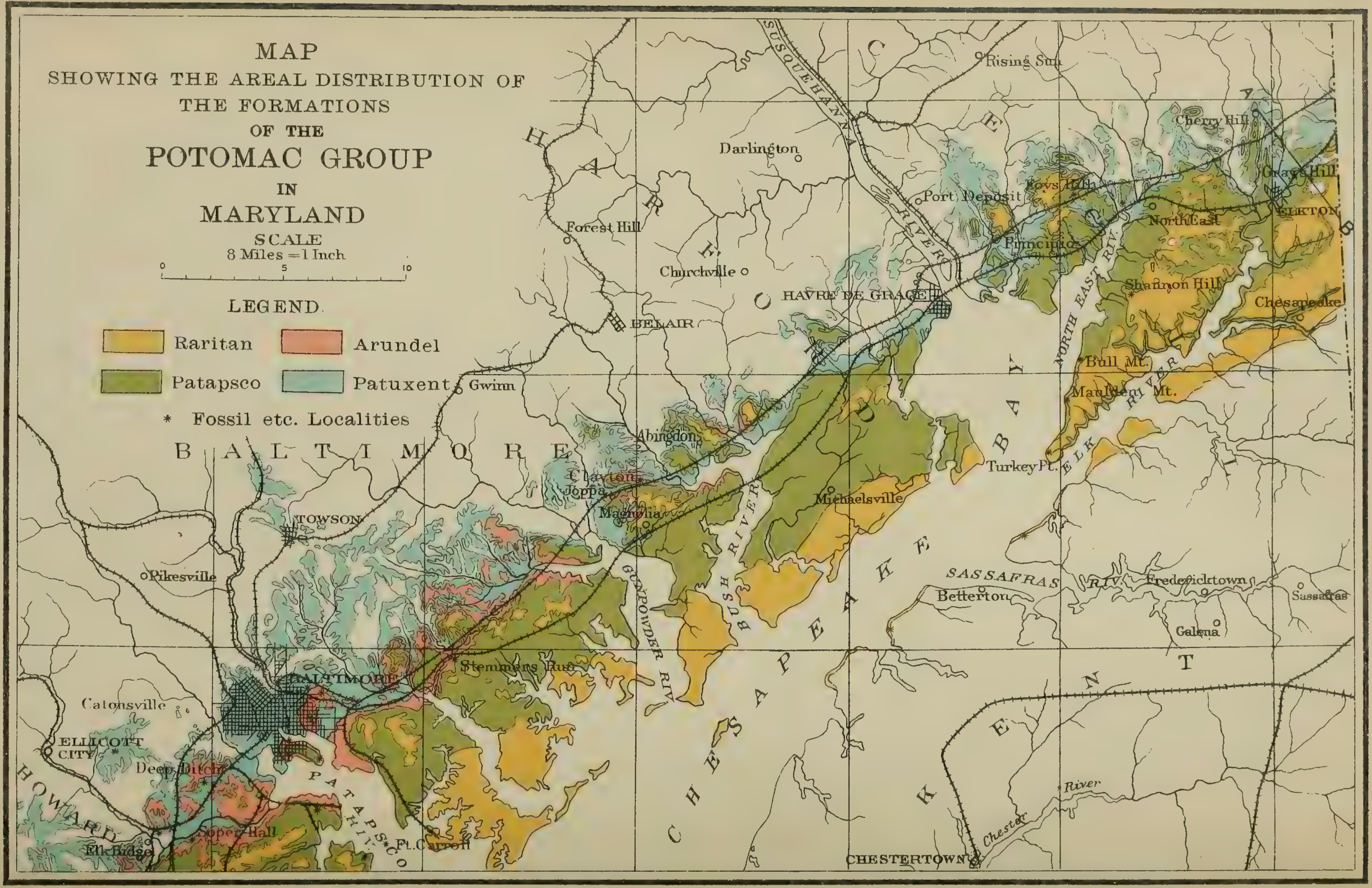
MAP
SHOWING THE AREAL DISTRIBUTION OF
THE FORMATIONS
OF THE
POTOMAC GROUP
IN
MARYLAND
SCALE
8 Miles = 1 Inch
0
5
10
LEGEND
Raritan
Arundel
Patapsco
Patuxent
* Fossil etc. Localities
BALTIMORE
HARFORD
CECIL
KENT
HOWARD
CHESAPEAKE BAY
SUSQUEHANNA RIVER
NORTH EAST RIV.
ELK RIVER
BUSH RIVER
GUNPOWDER RIV.
SASSAFRAS RIV.
PATAPSCO
Chester River
Rising Sun
Cherry Hill
Grays Hill
ELKTON
North East
Principio
Port Deposit
Foys Hill
Shannon Hill
Chesapeake
Bull Mt.
Maulden Mt.
Turkey Pt.
Darlington
Forest Hill
Churchville
HAVRE DE GRACE
BELAIR
Gwinn
Abingdon
Clayton
Joppa
Magnolia
Michaelsville
Fredericktown
Betterton
Sassafras
Galena
TOWSON
Pikesville
Stemmers Run
BALTIMORE
Catonsville
ELLICOTT CITY
Deep Ditch
Soper Hall
Elk Ridge
Ft. Carroll
CHESTERTOWN

Geology by Arthur Bibbins

DISTRIBUTION OF THE FORMATIONS OF THE POTOMAC GROUP IN MARYLAND

A. HOEN & CO. BALTIMORE.

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GEOLOGY OF THE POTOMAC GROUP IN THE MIDDLE ATLANTIC SLOPE

BY W. B. CLARK AND A. BIBBINS

(Presented before the Society December 31, 1901)

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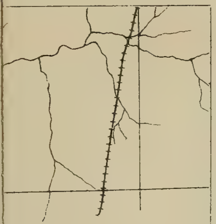
INTRODUCTION

Along the eastern border of the Piedmont plateau, lying for the most part directly on the flanks of its ancient crystallines and constituting the basal element of the Atlantic Coastal plain, is a series of mostly unconsolidated, arenaceous, argillaceous, and often ferruginous sediments of highly varied character. The outcrop constitutes a relatively narrow belt, extending from cape Cod to the Mississippi basin and ranging from a few to 20 miles in width, its landward boundary lying somewhat westward of the so-called Atlantic Fall line.

The general strike of the beds along the Atlantic border is northeast-southwest, the belt being divisible into three districts—northern, middle, and southern—whose strike is progressively more and more southward in passing from the northern district to the southern. The normal dip of the beds within the area of outcrop ranges from 30 to 60 feet per mile, a well marked increase occurring toward the landward margin and a decrease to the seaward. The thickness of the deposits, at the point where they pass beneath tide, ranges from 100 to 1,000 feet, dependent largely on whether the full sequence of formations is present or not. The main body of the deposits lies below tidelevel, although the strata occasionally reach 500 feet above sealevel along the western margin of the Coastal plain.

The belt crosses all of the principal waterways of the Atlantic slope, by which it is divided into a series of broad, low watersheds. The higher elevations have relatively steep and often irregular slopes, the region being one of comparative youth. The streams, when not tidal, are active, but the belt is frequently cut to its western margin by tidal estuaries.

The flora of these deposits includes thallophytes, liverworts, equiseta, ferns, cycads, conifers, monocotyledons, and dicotyledons. A conspicuous feature of the earlier and middle floras was the cycadaceous, one of the most important organic facts, and one which points as well to the prevalence of a subtropical climate as to the Mesozoic age of the deposits.



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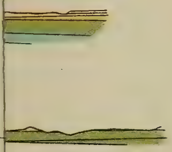

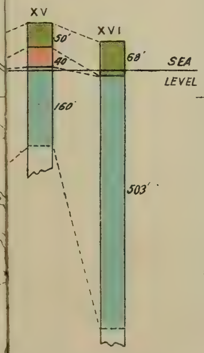
XV
XVI
50'
40'
160'
68'
503'
SEA
LEVEL

by Arthur Bibbins

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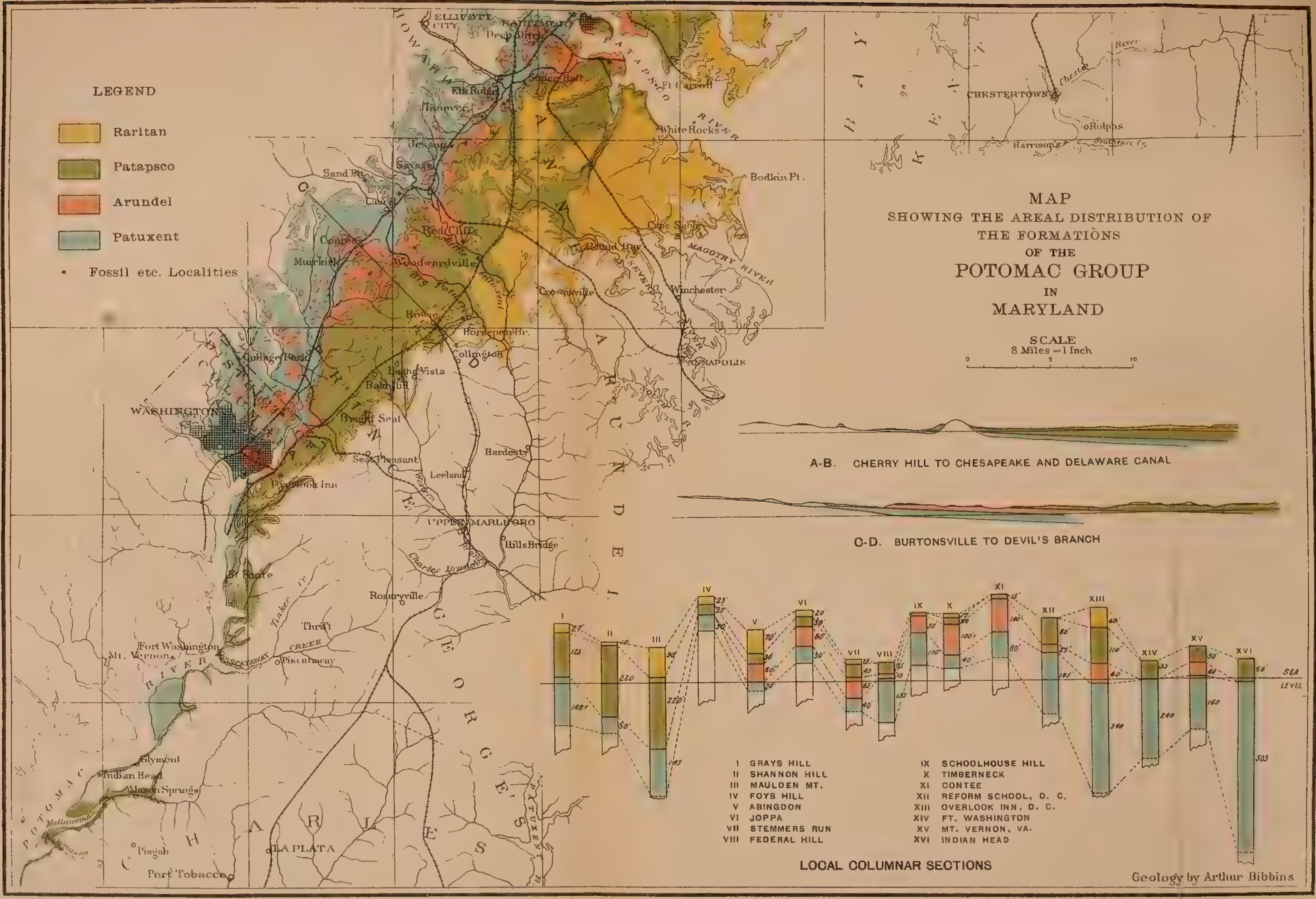
LEGEND
🟨 Raritan
🟩 Patapsco
🟥 Arundel
🟦 Patuxent
• Fossil etc. Localities
MAP
SHOWING THE AREAL DISTRIBUTION OF
THE FORMATIONS
OF THE
POTOMAC GROUP
IN
MARYLAND
SCALE
8 Miles = 1 Inch
0
5
10
A-B. CHERRY HILL TO CHESAPEAKE AND DELAWARE CANAL
C-D. BURTONSVILLE TO DEVIL'S BRANCH
SEA LEVEL
I GRAYS HILL
II SHANNON HILL
III MAULDEN MT.
IV FOYS HILL
V ABINGDON
VI JOPPA
VII STEMMERS RUN
VIII FEDERAL HILL
IX SCHOOLHOUSE HILL
X TIMBERNECK
XI CONTEE
XII REFORM SCHOOL, D. C.
XIII OVERLOOK INN, D. C.
XIV FT. WASHINGTON
XV MT. VERNON, VA.
XVI INDIAN HEAD
LOCAL COLUMNAR SECTIONS
Geology by Arthur Bibbins
ELLICOTT CITY
BALTIMORE
HOWARD
ANNE ARUNDEL
PRINCE GEORGES
CHARLES
MONTGOMERY
KENT
WASHINGTON
ANNAPOLIS
UPPER MARLBORO
LA PLATA
CHESTERTOWN
POTOMAC RIVER
PATAPSCO RIVER
MAGOTHY RIVER
BAY

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DISTRIBUTION OF THE FORMATIONS OF THE POTOMAC GROUP IN MARYLAND

The remains of conifers are considerably more common than those of other types, though such may not have been actually the case during that period, as the trunks of the former are much better adapted for preservation than most of the other forms.

The most variable element of the flora is the dicotyledonous. In the lower beds the forms are scant, as well as primitive in type. In the succeeding deposits they become progressively more and more specialized and abundant, until, in the uppermost beds, there is a wide range of highly organized genera and species with well marked modern affinities and a great profusion of individuals.

The fauna includes sponges, either worm or insect larvæ borings, insects, lamellibranchs, gastropods, fishes, and reptiles, including plesiosauria and dinosauria. Remains of the last mentioned group, including both diminutive and gigantic species, are by far the most important, and serve to confirm the evidence of the cycads as to the Mesozoic age of the deposits, as well as of the prevailing warm climate. The absence of any strictly marine fossils* and sediments, together with the presence of a few brackish water shells, point to estuarine conditions of deposition.

The sands and clays have been largely drawn upon for building and other purposes, and this fact, together with the alternately argillaceous and arenaceous character of its soils, early gave rise to the name "clay and sand belt."

The name "Potomac" was first applied to the lower and middle portions of these deposits by Professor W J McGee,† of the U. S. Geological Survey, who began his studies in the Potomac River basin near Washington, D. C.

It hardly needs mention here that the Potomac deposits have been the subject of a great amount of study by many independent workers, who have approached the problem from nearly as many different points of view. These facts, together with the proverbially complicated stratigraphy, have given rise to a highly varied taxonomy and nomenclature and a corresponding amount of not always the best-humored controversy. The views of the several writers, including those of the authors of this paper, as set forth in the Journal of Geology in 1897, are shown on the accompanying comparative taxonomic table.

It is believed by the authors that the Maryland section contains more facts on which to base a solution of Potomac problems than any other. To begin with, it is centrally located, well within the belt. A study of the margins of sedimentary formations is apt to convey erroneous impressions as to their character as a whole. Again, in central Maryland the Potomac beds reach their maximum breadth of outcrop, their greatest thickness, as well as their greatest lithologic and paleontologic diversity. With these facts clearly in view, the authors have attempted the interpretation of the Maryland area, and have brought to bear on its problems the results of a large amount of systematic field work in this region, as well as in the areas both to the north and south.

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*Spicules of sponges are often common in clearly defined estuarine deposits. They occur in abundance in recent estuarine sediments of the Chesapeake as far north as Baltimore.

† Report of health officer, D. C., 1884–'5 (1886), p. 20.

The constituent formations of the Potomac group, with the exception of the Arundel formation in part, dip at progressively lower angles from below upward, and in general gradually thicken down the dip within the limits of the area of outcrop, although they gradually thin farther to the seaward. Their stratigraphic relation is that of progressive transgression landward from the southwestward, the younger formations extending farther and farther toward the Coastal plain margin northward, until they successively come to rest on the Piedmont plateau. The general relations for the Maryland deposits are shown in the accompanying vertical and columnar sections.

Since the publication by the authors in the Journal of Geology in 1897 of "The Stratigraphy of the Potomac Group in Maryland" field investigations have been steadily in progress during the summer months under the joint auspices of the Maryland Geological Survey, the Woman's College of Baltimore, and the U. S. Geological Survey. Although the position taken by the authors in that paper was based on a moderate field knowledge of the Potomac beds, subsequent work has, in the main, confirmed the conclusions there stated. A great number of comparative sections have been made and collections of fossils obtained from many stations heretofore unknown. Detailed mapping, on the base of the U. S. Geological Survey topographic atlas sheets, is nearing completion in Maryland and the District of Columbia, and much work has also been done in Virginia, Delaware, Pennsylvania, and New Jersey. The lines for the Maryland area are shown on the accompanying map, reduced from those on the atlas sheets to a scale of 12 miles to the inch.

Descriptions of the constituent Formations of the Potomac Group in Maryland

THE FORMATIONS AND THEIR RELATIONS

In the Potomac deposits of the middle Atlantic slope four formations are recognizable, named in order of age the Patuxent, the Arundel, the Patapsco, and the Raritan. Their relations to one another and to their immediately subjacent and superjacent terranes are shown in the following table:

	Clark and, 18	N. H. Darton, 1893.	J. S. Newberry, 1895.	L. F. Ward, 1895.	O. C. Marsh, 1896.
CRETACEOUS.	RARI	Magothy.	Amboy clays.	Island series.	
				Albirupean series.	
				Iron ore series.	
	PATA	POTOMAC.		Aquia Creek series.	POTOMAC or JURASSIC FORMATION.
JURASSIC (?)	ARUN			Mt. Vernon series.	
				Rappahannock series.	
	PATU			James River series.	

Comparative Taxonomic Table

Clark and Bibbins, 1897.		W. B. Rogers, 1841.	J. C. Booth, 1841.	P. T. Tyson, 1862.	G. H. Cook, 1868.	W. B. Rogers, 1879.	Ch. E. Hall, 1881.	R. P. Whitfield, 1885.	W J McGee, 1888.	P. R. Uhler, 1888.	W. M. Fontaine, 1889.	N. H. Darton, 1893.	J. S. Newberry, 1895.	L. F. Ward, 1895.	O. C. Marsh, 1896.
Cretaceous.	Raritan.				Plastic clays (Woodbridge and Amboy clays).			Raritan clays.		Alternate clay-sands.		Magothy.	Amboy clays.	Island series.	
										Albirupean.				Albirupean series.	
			Red clay formation (Upper Secondary in part).				Wealden clay.		Upper or clay member.		Upper or clay member.			Iron ore series.	
	Patapsco.													Aquia Creek series.	
		Upper Secondary.		Upper Oölite (iron ore clays).		Jurasso-Cretaceous.			Potomac.	Baltimorean.	Potomac or Younger Mesozoic.	Potomac.			Potomac or Jurassic Formation.
Jurassic (?)														Mt. Vernon series.	
	Arundel.								(Varicolored clays).		(Variegated clays).				
														Rappahannock series.	
	Patuxent.			Lower Oölite (sands and clays).					Lower or sandstone member.		Lower or sandstone member.				
														James River series.	

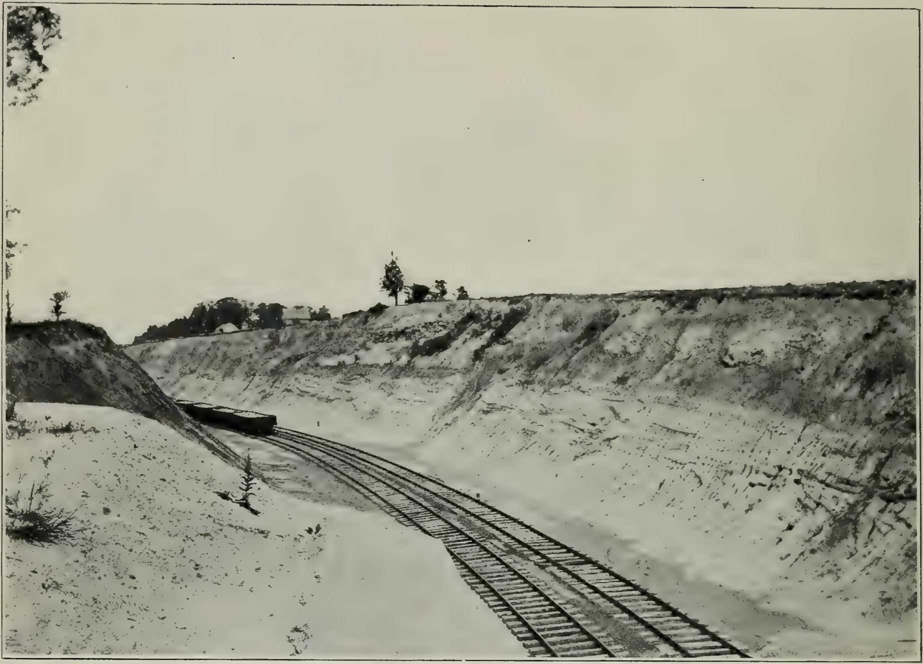

FIGURE 1.—BELT LINE (BALTIMORE AND OHIO RAILROAD) CUT, BALTIMORE CITY
Showing Characteristic Sands and Gravels

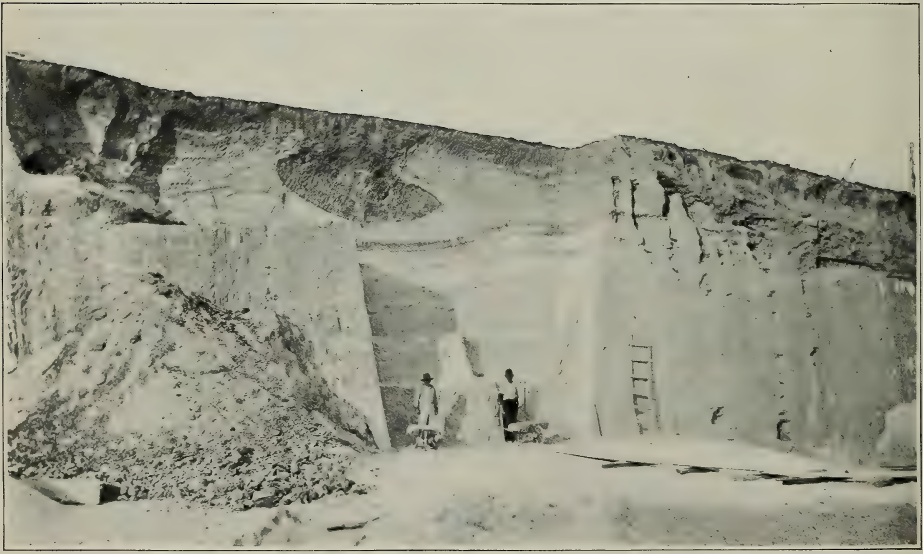

FIGURE 2.—SAND PIT NEAR WESTPORT, BALTIMORE COUNTY

PATUXENT FORMATION

Group.	*Formation.*	*Age.*	*Origin.*
Columbia	Talbot Wicomico Sunderland	Pleistocene	Marine, Estuarine, and Fluviatile.
	Lafayette	Pliocene	
	or		
	Aquia	Eocene	Marine.
	or		
	Matawan	Cretaceous	Marine.
Potomac	Raritan	Cretaceous	Estuarine.
	Patapsco	"	
	Arundel	Jurassic (?)	
	Patuxent	"	
	Newark*	Triassic	Estuarine and igneous.
	or		
	Crystalline rocks.	Algonkian (?)	Sedimentary and igneous.

PATUXENT FORMATION

Name and lithologic characters.—The Patuxent formation receives its name from the Patuxent river, in Maryland, in the basin of which the deposits of this horizon were first recognized as an independent formation and systematically studied. The deposits consist mainly of sands, at times quite pure and gritty, but generally containing a considerable amount of kaolinized feldspar (known as arkose), whence Roger's name "feldspathic sandstone" for its indurated derivative. Brown loamy sands are also common and are often indurated. Clay balls are at times distributed through the arenaceous beds, which in places contain lenses of gravel (plate 24, figure 1), sometimes with cobblestones several inches in diameter. Frequently the sands pass either abruptly or gradually over into sandy clays, and these in turn into more highly argillaceous materials, which are commonly of light color, but at times become lead-colored and lignitic and rarely iron-bearing. Massive red and variegated clays also occur, but they are of minor importance. They often bear a striking resemblance to certain of the crystalline residuals, from which they are directly derived by redeposition. Those arenaceous materials which chance to lie adjacent to ferruginous clays are not infrequently indurated by hydrous iron oxide, forming a characteristically corrugated ferruginous sandstone (occasionally inclosing oölitic sand) or conglomerate. The more arenaceous deposits are commonly cross-bedded and exhibit evidence of rapid deposition under varying conditions.

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*In Maryland the Potomac sediments rest directly on the crystalline rocks, the Newark formation lying on the western flank of the Piedmont plateau.

Organic remains.—The flora of the Patuxent formation includes equiseta, ferns, cycads, conifers, monocotyledons and a very few archaic dicotyledons, the coniferous and cycadean element being particularly strong. The known fauna of the Patuxent formation is limited to a single unio (Ward) and a fish (Fontaine).

Strike, dip, and thickness.—The general strike of the Patuxent beds in Maryland—and the same may be said of the other formations of the Potomac group—is northeast-southwest. Strictly speaking, however, the strike has toward the north a progressively more and more pronounced eastward trend, ranging from north-northeast to south-southwest to the southward of Washington to east-northeast to west-southwest at the head of Chesapeake bay. A well defined change in strike occurs at the head of the bay and another at or near Washington.

The directions of the dip of the Patuxent, as well as of the overlying beds of the Potomac group in Maryland, ranges from east-southeast toward the south to south-southeast toward the north. The amount of the normal dip of the basal beds of the formation reaches some 60 feet per mile. Along the Fall line or zone, which is toward the landward margin of the Patuxent outcrop, the dip of the basal Patuxent beds is considerably greater than this. South of Washington it ranges from 50 to 75 feet. Near the Potomac river the descent reaches some 90 feet per mile. The dip at other points is as follows:

	Feet.		Feet.		Feet.
Burtonsville	75	North of Joppa	60–80	Egg Hill	80
Laurel	65	Abingdon	100	Cherry Hill	60
Ilchester Hill	68	Harford Furnace	70	Barksdale	45
Relay	200	Carsins	100	Chestnut Hill	50
Catonsville	114	Aberdeen	109	Clifton Heights, Pa.	63
House of Refuge	75	Aldino	100	Sand Hills, N. J.	70
Baltimore	80–90	Webster	100	The basal Potomac beds of the Raritan River region, N. J. (Cook)	60
Towson	66	Havre de Grace	100		
Cub Hill	58	Battle Swamp	73		
Perry Hall	66	Theodora	100		
Loreley	100	Bay View	90		

From these facts we learn that along the zone of the Fall line the Patuxent deposits of the middle Atlantic border, barring two anomalous exceptions, often exhibit a considerably steeper dip than 60 feet per mile, the average for the section mentioned being 80 feet per mile; that this value exhibits considerable variation and reaches its maximum in the Patapsco depression at Relay at 200 feet per mile or more.

The position of the Patuxent deposits of the Lutherville-Timonium area is almost anomalous. Here the beds, which rest on crystalline limestone of Algonkian age, lie 100 feet lower than the base of the Patuxent at Towson, immediately southeastward. Moreover, they show a slight *northwestward* dip. A similar case occurs in the Conshohocken-Rubicam valley, some 12 miles north-northwest of Philadelphia, where the Patuxent beds, which also rest in part on marble, lie but 200 feet above tide. These sands and clays exhibit unmistakable evidence of local disturbance, due possibly to solution of their calcareous substrata. Whether these two cases are to be explained on the basis of sedimentation on an uneven surface, or to the downthrow westward or some other cause, remains to be determined.

The thickness of the Patuxent formation in central Maryland at the point where its summit passes beneath tide is about 100 feet. The greatest thickness of the exposed beds in a single section of the Maryland area occurs at Schoolhouse hill, Baltimore county, where they reach some 60 feet. At this station there is a heavy bed of Patuxent materials beneath, sufficient probably to raise the total thickness to at least 100 feet. Deep well borings to the southward suggest a well marked thickening of the deposits in that direction, as a glance at the section on the map will show. The well at Saint Elizabeth's Insane Asylum penetrated the Patuxent to a depth of 340 feet, and that of Indian head to a depth of about 353 feet without reaching the base. Allowance must, however, be made for the fact that these borings are at some distance from the margin of the Coastal plain.

Areal distribution and boundaries.—The Patuxent as the basal formation of the Potomac group occupies a position along the landward margin of the Coastal plain. In Maryland its outcrop begins near Indian head on the Potomac river and follows the river shore, generally beneath Potomac deposits of higher horizons to Anacostia, where it passes beneath tide. It extends to the westward beneath the city of Washington and continues northeastward in a deeply dissected and often interrupted belt through Laurel, Relay, Baltimore, Havre de Grace, Northeast, and Elkton to the Delaware line.

It incloses two sorts of Algonkian inliers. One of them, a depressed erosional inlier, due to perforation of the Patuxent terrane by stream erosion, is exposed at many points along the Fall Line zone, notably in the Gunpowder and Laurel quadrangles. The other, a raised original inlier, is exhibited at Grays hill, Maryland, and at Chestnut and Iron hills, Delaware, in the Elkton quadrangle. Though the Patuxtent beds surround these hills, there is no evidence that either this or the superior members of the Potomac ever covered them.

The Algonkian-Patuxent boundary.—This boundary is on the whole the least difficult of the Potomac lines to trace. The chief difficulties are found in the differentiation of certain massive red and variegated clays near and at the base of the Patuxent formation from residuals of similar character from which they were evidently derived by redeposition. Other residuals closely resemble Patuxent arkosic sands. In cases of imperfect exposures these resemblances are at times the occasion of considerable uncertainty.

Characteristic local section.—Tyson published in 1860 a record of the strata penetrated by an artesian well at "Smith's distillery," situated on Northwest harbor, Baltimore, which is an entirely typical Patuxent section. After passing through 52 feet of river mud, the well penetrated, at 42 feet below tide:

	Feet
1. Sand, gravel, and boulders	6
2. Hard blue clay	9
3. Red clay	6
4. Red ocher	5
5. White sand	4
6. White clay	32
7. White sand and gravel, water-bearing	8
8. White clay	3
9. White sand, gravel, and boulders, water-bearing	7
10. Gneiss rock	..
Total thickness	80

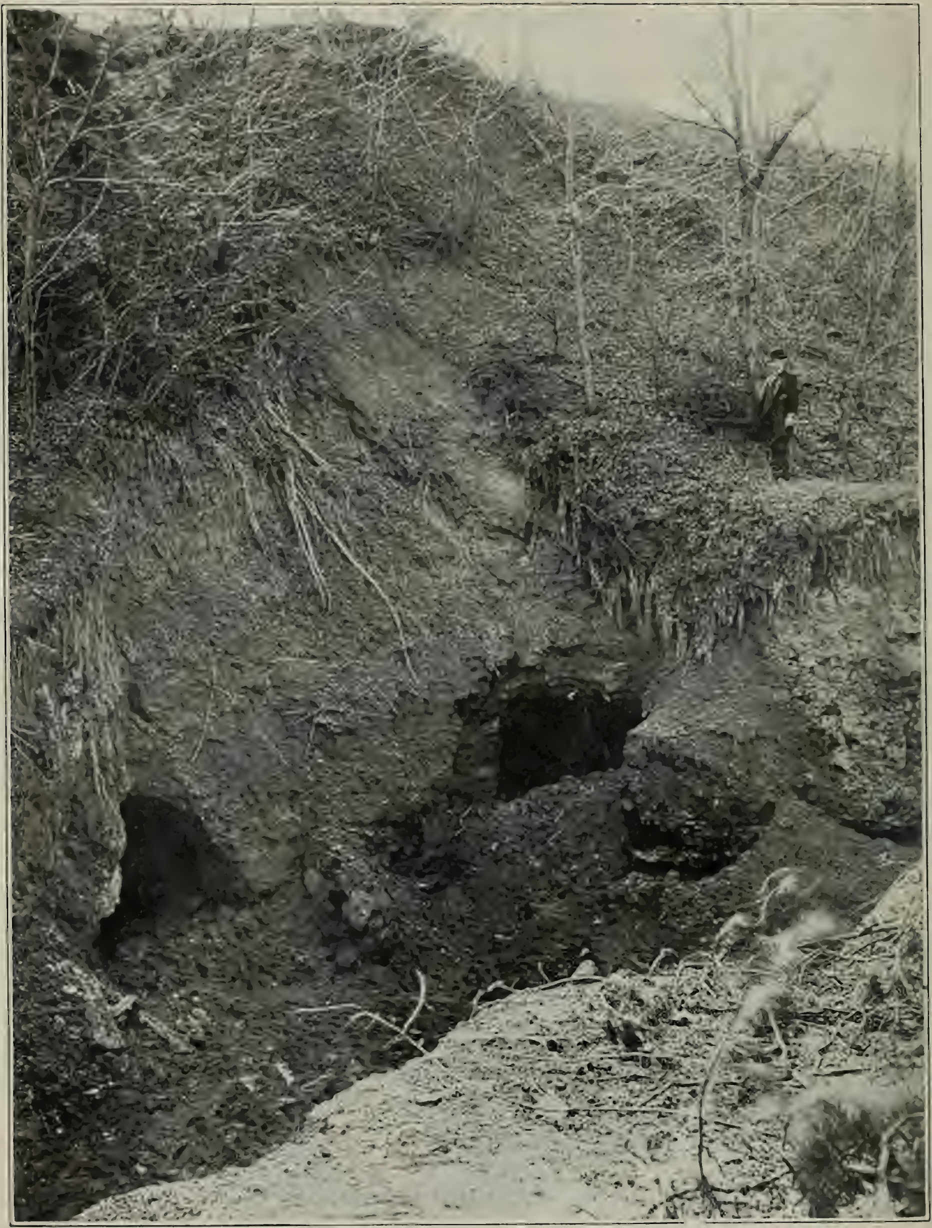
The "boulders" of the first and ninth members are doubtless cobble.

Economic products.—The Patuxent formation, which is on the whole an arenaceous terrane, yields building and other sands (plate 24, figure 2) on a large scale, and road metal in the form of arkosic gravel and iron sandstone and conglomerate. It also yields white and ferruginous clays to some extent as well as black lignitic clays which are in use as a base for pigments. Red and yellow ochers also occur. The drab clays contain a very few workable beds of iron carbonate.

ARUNDEL FORMATION

Name and lithologic characters.—The Arundel formation receives its name from Anne Arundel county, Maryland, where the deposits of this horizon are typically developed and well exposed.

The deposits consist chiefly of large and small lenses of drab or iron-tinted clays. These clays are frequently iron-bearing, the varieties being an earthy spathic ore, occurring in concretions, flakes, geodes, and layers, often in many courses. They are also at times pyritous and occasionally gypseous. The clays may be either massive, exhibiting slickensides surfaces, or laminated. In the latter case they are usually



Lignite Bed at Iron Mine, Soper Hall, Anne Arundel County

ARUNDEL FORMATION

more or less sandy. They often carry logs of coniferous lignite, usually lying in horizontal position and strongly compressed. Occasionally large upright stumps are encountered, standing where they grew, with the roots and trunks more or less replaced by iron carbonate and iron sulphide. The logs of lignite are not infrequently massed together into a well defined bed of considerable thickness and extent, which has been locally utilized by the miners for fuel (plate 25). The foliaceous remains and seeds of plants are apt to be found in the vicinity of these beds. At times the clay is charged with comminuted lignite, when it is known as "charcoal clay." This clay is apt to be rich in "charcoal ore," and at a few points bears osseous remains. It was one of these beds, situated near Muirkirk, Maryland, from which Mr Hatcher obtained for the late Professor Marsh a considerable collection of dinosaurian and other remains. In the upper portions of the formation, which have long been exposed to atmospheric influences, the carbonate ores have sometimes to a considerable depth changed to hydrous oxides of iron, known to the miners as "brown" or "red" ore. Under these conditions the originally drab-colored clays have suffered a like chemical change, resulting in red or variegated clays. When the Arundel clays at other levels contain scant vegetable matter, they are frequently highly colored, and if they contain ore it is of the red or brown variety and sometimes a red ocher ("Venetian red"). Red ocher generally occurs near the base or summit of the formation, but at times within the main body of the same. To the landward the formation is often arenaceous, and at times exhibits considerable lenses of sand.

Organic remains.—The flora of the Arundel formation includes algæ, fungi, lycopods, ferns, cycads (apparently fronds only), many conifers and monocotyledons, as well as a considerable showing of dicotyledons, which, though not specially advanced in type, are far beyond those of the Patuxent formation in grade as well as in variety and numbers. There is therefore a well defined contrast between the dicotyledonous elements of these two formations.

The fauna of the Arundel formation includes worms (or possibly the borings of insect larvæ), lamellibranchs, gastropods, fishes, and reptiles, including turtles and dinosauria, remains of the latter being comparatively common. Bones of cetaceans are alleged to have been found by Tyson, but the report lacks confirmation. Notwithstanding this, the faunal contrasts between the Arundel and Patuxent are seen to be strongly marked.

Strike, dip, and thickness.—The strike and direction of dip of the Arundel formation within the zone of its occurrence are practically identical with those of the Patuxent formation.

The normal dip of the formation is 40 to 50 feet per mile. At Baltimore it appears to be somewhat less than this. There is a well marked increase in dip to the landward, along or near the Fall line, as in the case of the Patuxent the average rate of descent at twenty stations being about 72 feet per mile, the range being from 34 to 190 feet. Abingdon, 34 feet; Joppa, 40 feet; Loreley, 93 feet; Stemmers run, 53 feet; Homestead (Baltimore), 60 feet; Loudon park, 50 feet; Relay, 80 feet, with one local dip of 133 feet and another of 190 feet; Hanover, 106 feet; Jessups, 40 feet; Annapolis Junction, 80 feet; Savage, 50 feet; Muirkirk, 62 feet; Beltsville, 60 feet; Branchville (local), 80 feet; Riggs' mill, 40 feet; Brookland, 40 feet; Washington, 64 feet.

The thickness of the Arundel formation ranges from 0 to 125 feet or more. The greatest thickness of the exposed beds occurs in the iron mines above Hanover and in the Muirkirk area. The data regarding the thickness of this formation to the eastward, where its summit descends below tide, are from artesian well borings, which must be accepted with caution. They tend to show that the formation does not thicken perceptibly along the dip beyond a certain point, and that the deposits lack horizontal continuity.

The Patuxent-Arundel boundary.—The Patuxent-Arundel boundary is on the whole the most clearly defined within the Potomac group. The occasional occurrence near the landward margin of the Patuxent formation of beds of drab lignitic clays, which are at times slightly iron-bearing and of massive red and variegated clays, although all of relatively small extent, has caused at a few points some uncertainty as to the true boundary line, owing to the fact that the strong increase in the dip of the Patuxent strata has brought its beds of clays into range with the normal dip of the Arundel clays. The difficulty has been further complicated by the occurrence of landslips, apparently dating back to the Quaternary, by which workable masses of Arundel iron ore clay were precipitated from elevated positions above the Patuxent sand and gravel, and are now more or less obscured by more recent sediments.

When organic remains can be found the problem is much simplified, since the floral and faunal contrasts are well marked. In the Patuxent terrane both plant and animal remains are comparatively scant, its dicotyledons being limited to a few very primitive types. In the Arundel, on the contrary, the remains of both plants and animals are relatively abundant. Normal, although still simply organized, dicotyledons are not uncommon. Dinosaurian remains, wanting in the Patuxent terrane, are comparatively common in the Arundel.

Though now for the first time cartographically shown, suggestions of the occurrence of the Arundel-Patuxent boundary have appeared from time to time in Potomac literature. The Patuxent beds have been designated as the " sandstone member " (Fontaine, McGee, and others), and its superjacent deposit as the " clay member." Tyson indicated in a general way on his map the position of the " iron ore clays " of the " upper oölite," the latter term evidently including everything in the Potomac above the Patuxent formation, which that author designated as the " lower oölite."

At points where the Arundel terrane is wanting, as in Cecil county, the tracing of the superior boundary of the Patuxent becomes more difficult, since there is a closer similarity lithologically between the Patuxent and the super-Arundel deposits than between the Patuxent and the Arundel. This difficulty is increased in the area named by the scarcity of organic remains.

Areal distribution.—The outcrop of the Arundel formation in Maryland occupies a comparatively narrow, irregular, and often interrupted belt extending from the city of Washington to Bush river. A few isolated areas of minor importance occur to the northward and to the southward of these points. At a number of places, notably to the northward, it is wanting in the sections, the deposits of the next higher horizon resting directly upon the Patuxent formation.

A very notable mass of exceedingly tough, drab, lignitic, and highly colored clays, apparently referable to the Arundel, but evidently barren of iron ore, constitutes the foundation of Capitol hill at Washington. A well boring, after passing through some 50 feet of recent and Pleistocene materials, penetrates 131 feet of these clays into the Patuxent sand and gravel. A great body of clays, apparently belonging to the same formation, is now being encountered in a deep sewer in the vicinity of Anacostia bridge.

Characteristic local section.—A section exposed at the Timberneck iron mine near Hanover is as follows:

			Feet
Raritan	1.	Reddish sands, at times gravelly, considerably indurated	12
Patapsco	2.	Red, white, and brown, more or less argillaceous sands, with clay pellets	20
Arundel	3.	Tough, drab, massive, pyritous clays bearing iron carbonate	100
Patuxent	4.	White clay, exposed in the bed of Licking run	5
		Total thickness	137

Economic products.—The best known economic product of the Arundel terrane is iron ore, whence the name " iron ore clays " of Tyson. There are several varieties of this, the best being an earthy spathic ore, occurring in nodules, flakes, geodes, and layers. It is locally known as " steel ore," on account of the exceptional toughness of the iron made from it. The names " white " and " hone " ore are also locally used on account of its color and fine grain. The ore which occurs in beds of comminuted lignite is thoroughly charged by the same, which circumstance is believed to materially aid in its reduction. This variety is known as "charcoal ore." Nodules of white ore weighing a ton are not uncommon, while ledges of the same have been encountered which require blasting, and when broken up have more than filled a railway car.

Other varieties, known as " brown ore," " red ore," etcetera, occur abundantly, often in the same beds with the white ore, from which they are generally derived by alteration near the surface. Both the brown and the white varieties include grades locally known as " velvet ore " from their fine, smooth grain and the beautiful druses of minute crystals of siderite and its derivatives which line the geodes and septarian nodules.

The " red ores " are apt to occur in clays scant in vegetable matter. These are used to some extent as pigments (Venetian red) and to impart desired tints to bricks, etcetera. Red ocher or " keel " also occurs in this formation, notably near the base, and yellow ocher to a less extent.

The Arundel formation has been worked for iron ore more or less continuously since the middle of the eighteenth century. A good part of our Revolutionary ordnance was made of it. At the present time, owing to the low price of iron, only a single furnace smelting Arundel ore is in active operation, but in former years they were scattered all along the belt from Bush river to Muirkirk, and their picturesque ruins are seen at many points.

The most prolific beds occur at Bush, Joppa, Stemmers run, Seven Mile hill, Baltimore, Elkridge, Hanover, Jessups, Annapolis Junction, Patuxent neck, Contee, Muirkirk, and Branchville. The principal workings at the present time are at Muirkirk, where the ore also is smelted.

The Arundel clays are extensively employed in the manufacture of brick and terra cotta, and to some extent for cement, pottery, and modeling. The supplies are inexhaustible, and they commonly lie conveniently for transportation either by land or water or both.

PATAPSCO FORMATION

Name and lithologic characters.—The Patapsco formation is so called from its typical occurrence in the valley of the Patapsco river. Its deposits consist chiefly of highly colored and variegated clays which grade over into or are interbedded with sandy clays, sand, and gravelly sand. Its arenaceous materials, particularly those lying adjacent to ferruginous clay beds, are often indurated, forming " pipe ore " or corrugated iron sandstone (plate 24, figure 1), at times conglomeritic. The "variegated clays," which commonly exhibit a great variety of exceptionally rich and delicate tints in extremely irregular "pied" patterns, often grade downward or horizontally into massive or stratified chocolate, drab, and black clays which are often lignitic, more or less pyritous, and occasionally iron and leaf bearing. The sands sometimes contain decomposed feldspar grains, as well as pellets and balls of white clay. They are frequently crossbedded, though less strongly marked than in the Patuxent formation. Red ocher, known as "paint rock" or "paint stone," occurs near the base and summit and sometimes within the formation, while flakes of sandy and ocherous limonite with botryoidal inferior surfaces are not uncommon at various horizons. The variegated clays often contain great numbers of small flattened pieces of limonite, quite uniform in dimensions. When these are brought to the surface by erosion, they form the resistant caps of innumerable miniature erosion towers which beset the crests and slopes of the verdureless "badland" areas, well shown at Bald hill, Prince George's county.

Organic remains.—The flora of the Patapsco formation includes ferns, cycads, conifers, monocotyledons, and dicotyledons, the last still constituting an inconspicuous element as compared with the other types represented. The range of genera and species is in the main limited, the grade of organization still moderately low, and the number of individuals scarcely greater than that of the preceding formation. At one station, however, near the summit of the formation there occurs a profusion of apparently a single species of leaf resembling Platanus.

The known fauna of the Patapsco formation is limited to a single, much worn, silicified, dinosaurian limb-bone, which was found at the surface and may have been redeposited from the Arundel.

Strike, dip, and thickness.—The strike of the Patapsco formation corresponds practically to that of the formations below it. The normal dip of its basal beds is from 35 to 40 feet per mile. This rate, as in the case of the preceding formations, is strongly emphasized to the landward at a few points, notably in the Principio area, where the formation reaches to the Fall line.

The thickness of the Patapsco formation in central Maryland at the point where its summit descends below tide is estimated at 240 feet. The greatest exposed thickness occurs at Grays hill, Cecil county, where it reaches 100 feet. At Broad Creek hill, south of New Glatz, Prince George's county, 80 feet of Patapsco clays are exposed.

The Arundel-Patapsco boundary.—The Arundel-Patapsco line represents very nearly the line of demarkation between the iron-bearing clays proper, with their barren equivalents and that great mass of variegated clays, etcetera, mostly barren of iron, which lie between this line and the base of the next succeeding formation. In general the demarkation is well defined, and in many local sections, notably in the Timberneck area, the contact is sharp, leaving little room for doubt that we have to do with something more than local changes in lithology or the effects of other varying local conditions. To the seaward, however, the line is by no means as clearly defined, and there is a suggestion of gradation, as at Federal hill. Again, the circumstance that the two formations are on the whole argillaceous, and the character of their clays often very similar, increases the difficulties of tracing the details of this boundary, and to this may be added the fact that the contrast in the floras and faunas is by no means as well marked as in the case of the Arundel and Patuxent. On the whole, therefore, it may be said that a more intimate relation exists between the Arundel and Patapsco than between the Arundel and Patuxent.

Areal distribution.—The Patapsco formation outcrops in an irregular, crescentic belt, deeply dissected along the drainage lines and often having its subaerial portion interrupted at the principal waterways. It extends from below Indian head on the Potomac to and beyond the head of the Chesapeake bay. To the northward the outcrop is narrow. It broadens toward the center of the belt and narrows again to the southward by virtue of the transgression of the superjacent terranes. In Cecil county, where the Arundel formation is wanting, the Patapsco beds repose directly on those of the Patuxent terrane, and the same is true over a number of smaller areas to the southward. The most notable body of Patapsco materials occupies the highlands between Branchville and Bowie.

Characteristic local section.—The following section occurs at Red hill, Cecil county:

		Feet
Raritan	1. Coarse reddish sand and coarse, evenly bedded, dark-brown iron sandstone	10
“	2. Yellow and buff sands and corrugated iron stone containing ferruginated coniferous wood; sand beds near the base, which is marked by springs	10
“	3. Tough white clay	7
Patapsco	4. Massive variegated red and drab clays, the latter slightly lignitic and with obscure leaf impressions; lenses of white sand toward base	130
Patuxent	5. Sands not exposed at surface	60

Economic products.—The Patapsco formation, although on the whole an argillaceous terrane, is often arenaceous, particularly to the landward, where it yields building sands and iron sandstone for road metal.

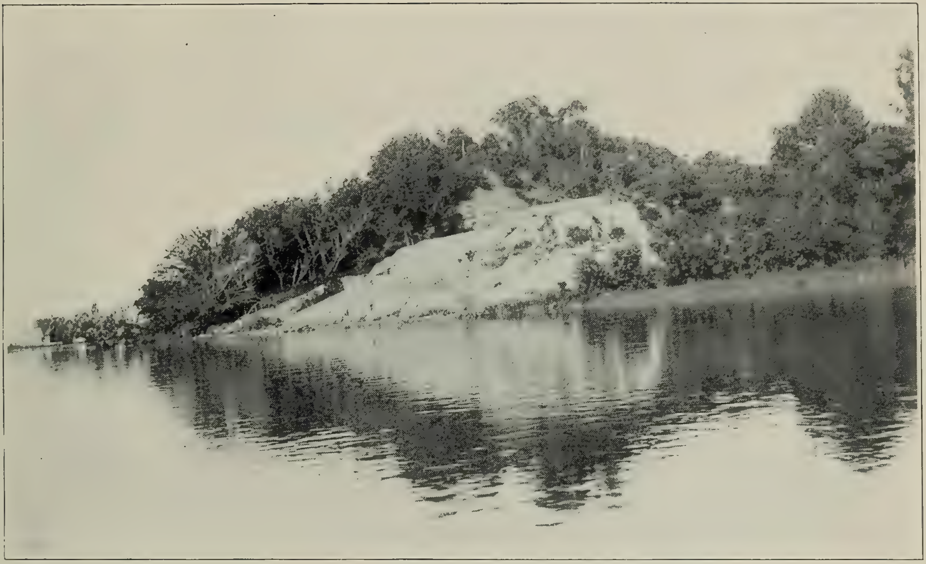


FIGURE 1.—VARIEGATED CLAYS BENEATH THE MATAWAN AT FORT WASHINGTON, PRINCE GEORGES COUNTY

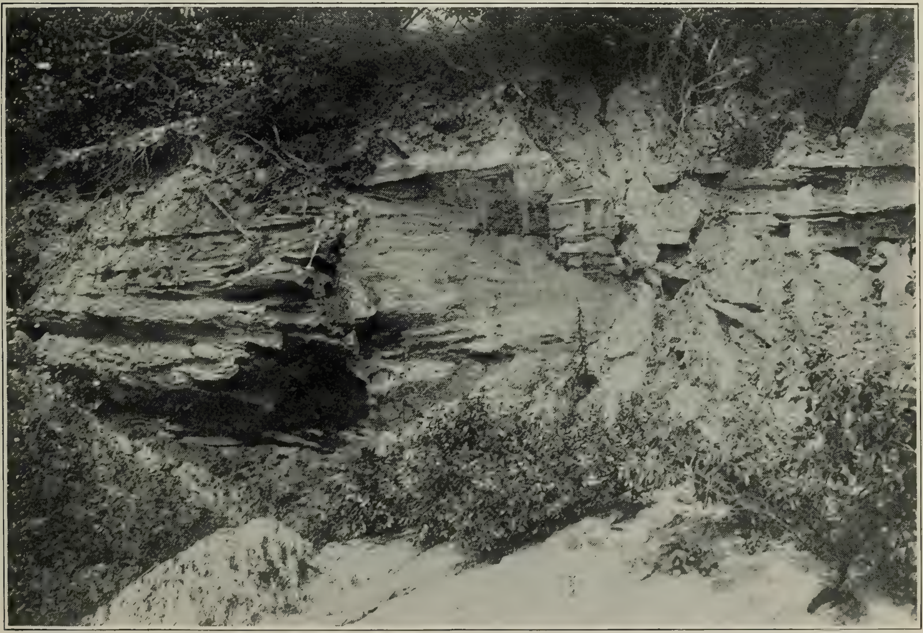


FIGURE 2.—CORRUGATED FERRUGINOUS SANDSTONE NEAR HANOVER, HOWARD COUNTY

PATAPSCO FORMATION

Its variegated and drab clays, beside constituting vast supplies for the manufacture of terra cotta, brick, etcetera, contain a few workable beds of iron carbonate. The base of the formation is the principal source of the well known Maryland "Venetian red" ocher, which also occurs near its summit. There is a tradition among the inhabitants of the Patapsco belt to the effect that this ocher was formerly used by the Indians for war paint. This rumor is substantiated by the fact that we find on their deserted village sites cobbles of "paint rock," evidently derived from the Potomac beds, which exhibit on their flat surfaces numerous scratches which are clearly attributable to human agency. In Cecil county the basal Patapsco clays, like those of the Patuxent, are highly charged with diffused lignite and are employed to some extent as a base for black pigments. In this area also the base of the formation yields a fine, micaceous "fire" sand.

RARITAN FORMATION

Name and lithologic characters.—The Raritan formation receives its name from the Raritan river, New Jersey, in the basin of which the deposits of this formation are typically developed. The name was given by the senior author of this paper in the annual report of the state geologist of New Jersey for 1892, although the term "Raritan clays" had been somewhat loosely applied to deposits of this age by earlier writers.

In the case of the Patapsco formation it was shown that the argillaceous character was the more prominent. In the Raritan the arenaceous features are emphasized. This is particularly true of the upper portions of the terrane. The sands are often of very fine texture, and when mixed with white clay are known as "fuller's earth." They occasionally contain white clay pellets and balls, and are at times gravelly. They are commonly white, but, particularly in the lower portions of the formation, are often stained by iron oxides. A notable illustration of such coloration occurs on the west shore of Elk neck near the meridian of 76°.

Induration of the sands by hydrous iron oxide is common, the resulting rock being either a very hard,* tubular or corrugated iron stone often having a metallic resonance, or a softer, evenly bedded, brown sandstone, suitable for building purposes. A well known illustration of the former variety is the Black rocks of the Patapsco, while the latter is quarried to some extent at Sandy Brae, in Cecil county. At times the presence of a trace apparently of a vegetable oil imparts to the rock a brilliant iridescence. This feature is also well exhibited at the Black rocks.

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*The deserted village sites of the Patapsco Indians which lie within the Potomac belt have yielded a number of arrow-points, spear-heads, and axes made of this rock.

Sometimes the Raritan sands are cemented by silica, producing a highly resistant rock resembling quartzite. An illustration of this occurs at the White rocks of the Patapsco river which afforded the name "Albirupean" applied by professor Uhler to the upper portions of the Potomac group (plate 27, figure 1).

The clays are commonly of light color or white. Sandy, white clays occur on a large scale. These, like the fine arkosic sands, are locally known as "fuller's earth" (plate 27, figure 2). At times the clays become dark colored, lignitic, very slightly iron-bearing, and richly leaf-bearing. They may be either laminated or less frequently massive, and at times exhibit a conchoidal fracture. A characteristic bluish drab tint, with a tendency toward lamination, serves to distinguish them, as a rule, from the drab Patapsco clays. Variegated or "pied" clays greatly resembling the "variegated clays" proper of the Patapsco formation also occur, but they are commonly more sandy and of somewhat lighter tints, often pinks, being known to the northward as "peach-blossom" clays. The Raritan variegated clays are also apt to exhibit obscure stratification and were probably redeposited from the Patapsco. The scale upon which they occur is inconsiderable as compared with those of the Patapsco, and the formation is on the whole considerably less argillaceous and also less homogeneous.

Strike, dip, and thickness.—The strike and dip of the Raritan formation in Maryland correspond, in a general way, with those of the preceding terranes. The normal dip of the basal beds of the formation is about 30 feet per mile. When the deposits extend landward as far as the Fall line, as in Cecil county, there are well marked increases in dip. An artesian well boring at Rock Hall, on the Eastern shore of Maryland, encountered the Raritan beds at 240 feet below tide level, indicating a dip of 34 feet per mile for the deposits of central Maryland.

The thickness of the Raritan formation in central Mayland, along the line where its upper beds descend below tide, is estimated at 240 feet. The greatest thickness of the exposed beds in a single section occurs at Maulden mountain on the west shore of Elk neck where it reaches nearly 70 feet (plate 27, figure 2).

Beds of black, massive, pyritous, earthy lignite, bearing prostrate trunks of lignitized conifers, honeycombed by Teredo, and associated with layers of comminuted lignite, occur near the summit of the formation. Overlying these are beds of coarse and fine, often crossbedded, slightly lignitic, white and buff sands with interlaminated brown sandy loam. These are often indurated. This entire series, which is best exposed at cape Sable, on the Magothy river, comprises the so-called "alternate clay-sands" of Uhler and the "Magothy formation" of Darton.

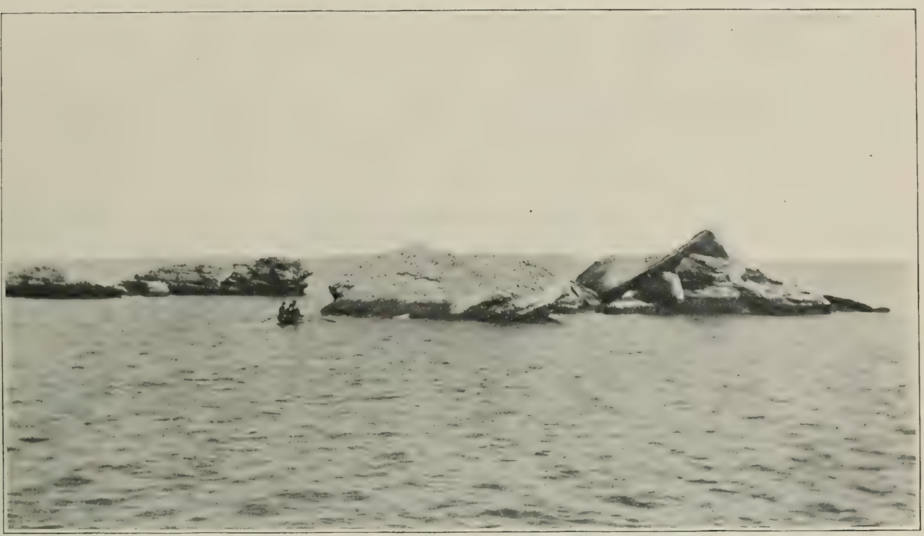

Figure 1.—Sandstone Ledges ("White Rooks") near Mouth of Patapsco River

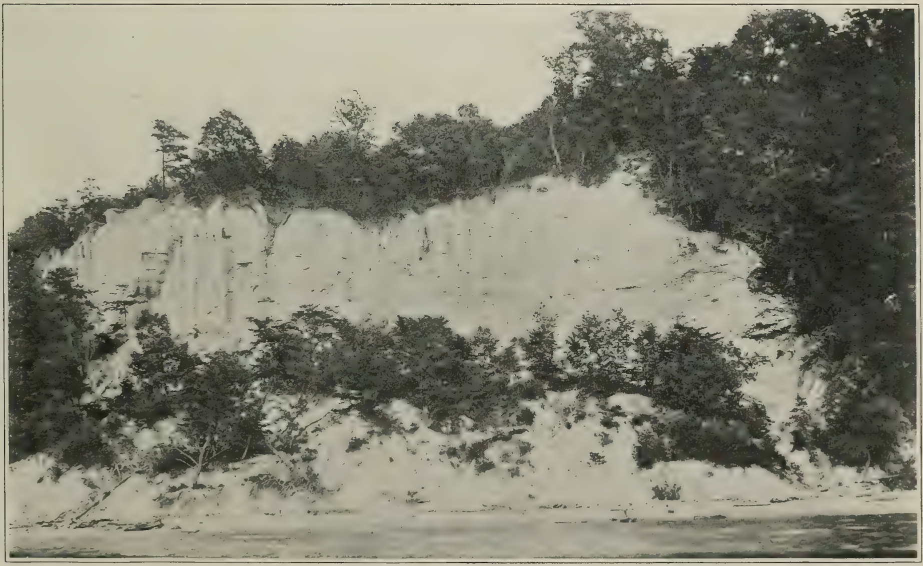

Figure 2—Cliff of "Fuller's Earth" Overlying Sands and Clays at Lower White Banks, Elk Neck, Cecil County

RARITAN FORMATION

The lignite of the Raritan is, as a rule, in a noticeably less advanced stage of carbonization than that of the preceding terranes, being often of brownish tint, and the logs somewhat less laterally compressed.

The Raritan formation yielded the first American amber. Its original source, cape Sable, on the Magothy river, was described in great detail by Troost early in the last century.

Organic remains.—The known flora of the Raritan formation includes a thallophyte, a lycopod, ferns, conifers, cycads, monocotyledons, and dicotyledons. No silicified stems or frond impressions of cycads have been found in undoubted Raritan beds in Maryland, although certain fronds have been reported by Newberry from the Amboy clays of New Jersey. The endogenous element is weak and the exogenous particularly prominent. There is a wide range of genera and species, with strong modern affinities.

The known fauna of the Raritan formation in Maryland is limited to a single species of Teredo and possibly an insect. Borings of the former are often met with in the trunks of lignitized conifers, so much more commonly, in fact, than in the preceding formations as to suggest a somewhat increased salinity of the Raritan waters. Four genera of lamellibranchs are reported by Whitfield from the Raritan clays of New Jersey, one with well marked Jurassic affinities. The clays of that area are also reported by Cope to have yielded a pleseosaurian bone.

The Patapsco-Raritan and Raritan-Matawan boundaries.—Though at times extremely obscure, owing to local similarities in lithology, the Patapsco-Raritan line is not on the whole a very difficult one to trace. The leaf beds, which are so much more common in the Upper than in the Middle and Lower Potomac, are a great assistance with their strongly exogenous and modern facies.

The Raritan-Matawan boundary is not at all points as readily discernible as might be expected. The clay marls of the marine Cretaceous at times so closely resemble the Raritan carbonaceous clays that even the most careful observers have confused them. The well known "black clays" of Grove point, Maryland, containing little or no glauconite and much pyrite, have as often been referred to the Raritan as to the Matawan and by equally careful observers.

Areal distribution.—The outcrop of the Raritan formation in Maryland occupies a crescentic and deeply dissected belt, often interrupted to the landward, extending from the District of Columbia to the eastward of Baltimore, across Elk neck to and beyond the Delaware border. Outcrops occur along the "Eastern shore" as far southward as Fairlee creek.

Characteristic local section.—The most comprehensive section of the Raritan deposits of Maryland occurs at Giller's hole, Maulden mountain, on the west shore of Elk neck.

Maulden Mountain, immediately above Giller's Hole.

			Feet
Columbia	1.	Loam and gravelly loam	6
Matawan	2.	Massive micaceous glauconitic sands, mottled with brown, oxidized, and more or less indurated near the top	30
	3.	Loose, lighter-colored sands, with less glauconite, oxidized at the surface (brown flecks)	6
	4.	Sharp white and yellow sands, indurated at the base	3
	5.	Yellow, red, and ash-colored sandy clays	2
	6.	Loose sands, micaceous and more argillaceous toward the base	15
	7.	Lens of loose carbonaceous and pyritous sandy loam, gravelly at base	6
Raritan	8.	Lens of stratified, iron-stained, at times pebbly "fuller's-earth" clay, occasionally lignitic (dicotyledenous? stems), indurated at base	3-10
	9.	Light buff and brown crossbedded sands, coated with "fuller's earth"	25
	10.	Ledge of corrugated iron sandstone	2-9
	11.	Sands similar to 9, brightly iron-tinted in the middle and lower portions and containing white clay pebbles and pellets; undulating base	15
Patapsco	12.	Massive variegated and drab lignitic plastic clays, the latter at times containing iron carbonate; obscured by talus and land slip	20
		Total thickness	138

Economic products.—The economic products of the Raritan formation in Maryland include building and glass sands, quartzose and ferruginous sandstones for building purposes and road metals, clays used in the manufacture of buff face brick and pottery, drab clays used for stoneware and modelling, and variegated and red clays also used at times for pottery. White sandy clay and white arkosic sand, known as "fuller's earth," occur on a large scale, and are in local use for polishing metallic surfaces. This will doubtless prove to possess wider economic possibilities. Massive pyritic deposits occur in workable quantities at a few points, notably at cape Sable, on the Magothy river, where they were mined early in the last century, and alum, copperas, and sulphuric acid produced. The amber already mentioned as occurring at this station is only of scientific and historical interest.

Interpretation of the Potomac Deposits

In their former paper the authors pointed out that Potomac deposition was probably preceded by extensive baseleveling of the eastern side of the continent, with widespread rock disintegration. Stimulated by elevation and seaward tilting, erosion afforded the materials of the Potomac group. The fact that these consist very largely of redeposited Piedmont crystallines, and to a less extent of Appalachian materials, is therefore what might be expected, but the circumstance that no clearly defined trace of redeposited Newark materials has been found in the Potomac deposits of Maryland is at first thought somewhat surprising. From this we must infer either that the Newark was not to any great extent exposed to Potomac erosion, or that its materials were not sufficiently consolidated to permit of transportation except in a so finely divided condition as to be unrecognizable. It is quite certain that during maximum Potomac subsidence a large body of Newark materials, especially beyond the limits of Maryland, was beneath tidelevel, and therefore not exposed to subaerial influences. Inasmuch as the Potomac beds themselves, particularly the basal ones, have since that date undergone considerable induration, often without the agency of iron oxide, we may suppose that the subaerial Newark sandstones of that date, if consolidated at all, were considerably less resistant than, for example, during the early Pleistocene, in the deposits of which the Newark materials are abundantly represented.

The basal deposits of the Potomac group, produced by the initial tilting of the continental border and described as the Patuxent formation, indicate in their arkosic character their proximity to the ancient continent, the rocks of which had suffered extensive disintegration. These features, which are so pronounced where the deposits lie adjacent to highly feldspathic rocks, largely disappear where these rocks are poorly developed or where the deposits themselves were evidently laid down at some distance from the old shoreline. Rapid deposition in shallow waters is seen in the crossbedded character of the strata and their rapid change in lithologic characters. The presence of clay pellets and balls in the sands of this formation, suggesting at first thought the existence of subjacent pre-Patuxent sedimentary clays, may represent local shallowing of the seas with the destruction by wave action of lately deposited Patuxent clay beds and the incorporation of their rolled materials into the later deposits of the same formation.

That the seaward tilting was not continuous or persistent in the same direction is evidenced by the varying character of the deposits and the stratigraphic relations which the several formations sustain to each other.

The close of the Patuxent epoch was marked by the elevation of its deposits and the trenching of its surface by streams. This was succeeded by a subsidence which was emphasized to the landward by the occupation of the ancient valleys by swamp deposits. The tough clays of the Arundel formation, charged with lignitic accumulations, in which tree trunks are at times found erect with their roots intact, find their most satisfactory explanation on this basis. It was in these ancient marshes that the iron, derived to a considerable extent from the adjacent area of basic eruptives, was deposited, first, no doubt, as bog ore, which by contact with lignite was later altered to the carbonate and redeposited in its present nodular form. It was in these marshes that the remains of dinosauria became entombed, which, with the evidence of dense vegetation, suggests subtropical climate.

On this hypothesis the lenses of Arundel clays, particularly to the landward, represent crudely the ancient drainage lines of the eroded surface of the Patuxent terrane. The widening of the areas seaward may possibly be interrupted on the basis of lagoon deposits into which the Arundel estuaries merged. That the waters in which the Arundel deposits were laid down were not entirely cut off from the sea is evidenced by the occasional occurrence of Teredo-bored conifers, while the absence of strictly marine fossils suggests that the Arundel waters had but imperfect marine communication.

It has been suggested by the students of the Maryland Pleistocene that the "buried-forest" deposits of the Chesapeake shores may furnish some clue to the origin of the Arundel iron ore clays. These deposits appear to have originated by the impounding of the estuaries by sand spits—a process which may be observed at many points within the Chesapeake and elsewhere at the present day. The closed estuary then speedily silted up and was converted into a peaty cypress swamp, in which bog iron ore was deposited. Meanwhile the bay shore adjoining the mouth of the swampy estuary was gradually receding by virtue of wave action until the swamp materials themselves were invaded and more or less cut away. This process was followed, or perchance attended, by gradual subsidence, which resulted in the deposition on the newly wave-cut surface of a new and later member. Emergence followed, and the waves are now actively cutting away both the more recently deposited terrane and the basal remnant of the older one, with its beheaded cypress trunks and their knees, imbedded in peat. In the basal clays of the swamp deposit, penetrated by the roots of the trees, one finds an occasional, imperfectly formed nodule of iron carbonate. When exposed to the air it rapidly changes to a bright vermilion ocher.

There is little question that some such process as this has figured to a considerable extent in the genesis of certain of the lesser lenses of drab, lignitic, iron-bearing clay occurring at various horizons throughout the Potomac group; but the grand scale—both vertical and horizontal—on which the Arundel formation, or "iron-ore clays" proper, were laid down cannot well be explained entirely by this simple theory. The idea of landward tilting, also, which appears to find additional support in the very indefiniteness observed at certain points in the Arundel-Patapsco boundary, must therefore be retained until a more satisfactory interpretation can be brought forward.

The well marked unconformity occurring at many points between the Arundel and Patapsco formations, notably in the West Hanover district, indicates emergence and a distinct erosion interval prior to Patapsco deposition. At points somewhat farther seaward and at lower levels, as at Federal hill, the line is less distinct and there is a suggestion of gradation. These facts would seem to indicate that the elevation was not an extensive one, bringing only the landward margin of Arundel deposits under the influences of subaerial erosion. In cases where this erosion resulted in a mere shoaling of the waters only a comparatively slight change in lithology and organic remains would be expected. It is certain that the tendency of the more recent investigations on these two formations has been to show that they are more closely allied than was formerly supposed—stratigraphically, lithologically, and paleontologically.

The highly colored and variegated clays of the Patapsco formation were evidently deposited in the quieter and deeper waters of this epoch, and, like the iron-bearing Arundel clays, bear some relation to the great basic eruptive masses, plentifully iron-bearing, which lie to the north and west of them. This phase of the sedimentation is somewhat more prominent in central Maryland, where the rocks of this character are not only well developed, but nearest the eastern margin of the Piedmont belt. It is also probable that these ferruginous Patapsco clays were also in part redeposited from the more richly iron-bearing clays of the subjacent Arundel. The Patapsco sands were doubtless derived to a considerable extent from those of the Patuxent terrane.

The unconformity separating the Raritan from the underlying deposits is likewise more pronounced to the landward and apt to be obscure to the seaward. To the landward also the lithologic break is more clearly defined. That a considerable erosion interval occurred is evidenced by the undulatory character of the Patapsco-Raritan contact and by the marked advance in the grade, variety, and number of the Raritan dicotyledons. The source of the Raritan materials was clearly in part the sands and clays of the preceding formations. The common occurrence of white sands, "fuller's earth," and white and generally light-colored clays marks another step in the gradual loss of iron in the progressive redepositions of the more richly ferruginous materials of the preceding deposits.

That the conditions of deposition, which the heterogenous character of the deposits show to have been highly varied, were, especially toward the last, considerably nearer the marine is indicated by the much more common occurrence and more active operations of Teredo.

Raritan sedimentation was closed by an uplift more strongly marked than before to the landward. The westward portions of the terrane were extensively eroded, and resubsidence inaugurated Matawan sedimentation. This depression of the continental border was distinguished from the others by its extent, which was such as to inaugurate the deposition of more or less well defined marine sediments, including greensands, at points where only estuarine materials were laid down during preceding epochs; hence the term "Marine Cretaceous," which has been often used by geologists to distinguish the later Cretaceous deposits from those of the earlier estuarine beds of the Potomac group.

The distinctly estuarine character of the Potomac sediments points to the existence for a long period of an extensive area of more or less brackish water along the eastern border of the North American continent. It must have reached at least from cape Cod to the Gulf. That it was either a sound, a lagoon, an embayment or an estuary, or a series of these, on a vastly greater scale than any along the Atlantic coast today, is probable. McGee's recent studies of the gulf of California suggested the possibility of an Atlantic barrier comparable in scale to the peninsula of Lower California. The evidence available, however, to establish the actual existence of any such type of barrier in early Cretaceous time appears to be scant. The comparatively sudden appearance of marine sediments which marked the beginning of the Upper Cretaceous points, to be sure, to the disappearance of some form of barrier, but what may have been its character or extent seems impossible of determination with the facts at hand. In the succeeding chapters the surface configuration both of the crystalline floor and of the Potomac group is discussed, and some possible interpretations advanced.

The greater thickness of the formations of the Potomac group along a belt somewhat to the eastward of the Fall line may have emphasized the downward movements in this portion of the Coastal plain during Potomac time. On the other hand, the gradual removal of the weight over the Piedmont region by the removal of its residuals has occasioned an upward movement of that area as well as immediately adjacent Coastal Plain regions. The accumulating results of these tendencies, particularly the first mentioned, from the beginning of Potomac time until the present, have been the weakening of the crystalline floor near the landward border of the Coastal plain accompanied by monoclinal folding and even faulting on a limited scale. McGee's studies of the upper Chesapeake area, and others to the northward and southward, fully convinced that author some years since that displacement had actually occurred, though no very definite evidence was adduced in demonstration of the same. Other writers, including Fontaine, however, believe that we have to do merely with sedimentation across a pre-Potomac escarpment. In the opinion of the authors of this paper, the Fall Line phonomena in Maryland, and elsewhere, afford considerable evidence of monoclinal flexures merging into simple and compound faulting. A number of carefully constructed vertical sections on a large scale have been made across the Fall Line zone, and these show in nearly every instance evidence of one or the other of the above mentioned phenomena, along with the marked increase in the dip of the Potomac deposits already mentioned.

Evidence of the actual displacement in the Potomac beds is most clearly defined in the vicinity of Relay, Maryland, and the evidence is strengthened by the fact that the Miocene beds of Catonsville lie considerably higher than the normal dip of the main body of the Miocene deposits calls for.

At the openings of the Maryland Clay Company, at Northeast, Maryland, there occurs a well defined example of an anticline in the Patuxent beds, which is believed by Ries to have been produced by the hydration of the subjacent feldspathic rock in the process of its decomposition into the residual koalin mined at this point. Though the scale on which the folding occurs is small, the phenomena afford a suggestion as to the possible causes of some of the lesser irregularities in the Patuxent beds which lie near the crystalline floor.

SURFACE CONFIGURATION OF CRYSTALLINE FLOOR AND ITS RELATION TO POTOMAC BASIN OF DEPOSITION

The basal beds of the Potomac group rest on a more or less uneven surface of crystalline rocks, in which certain of the more important drainage lines of the present day were already established, as is shown both by the marginal contacts and by the well borings near the landward border of the formations.

The great increase in the dip of the Patuxent and succeeding formations along the Fall line has already been alluded to, as well as the evidence that it represents in part at least a fault scarp.

It is significant, however, that there is a marked though less pronounced decline in the dip of the strata eastward of the Fall line all the way to the seaward margin of the Coastal plain. The evidence for this is furnished by the deep-well borings in Delaware, Maryland, and Virginia, the number of which is not as great as could be desired, although they all show, without exception, a progressively lessened dip of the beds as the distance from the landward margin increases.

The following wells of the middle Atlantic slope reach the crystalline rocks and show the following rates of descent of the crystalline floor:

Location of well.	Distance from point where Algonkian surface reaches tide level.	Depth of Algonkian surface below tide level.	Rate of descent per mile.	Thickness of the Potomac deposits.
	Miles.	*Feet.*	*Feet.*	*Feet.*
Ice works, South Wolf street, Baltimore	$\frac{3}{4}$	150	200	*122
Farnhurst, Delaware	2	111	55+	*211
Baltimore copper works	2	187	93.5	Unknown
Sandy point, Virginia	2	270	135	*170
Quantico, Virginia	2	210	105	*210
Indian Head, Maryland	$5\frac{1}{2}$	......	......	421.5+
Middletown, Delaware	12	452	37.7	302±
North End point, Virginia	72	1,162	15.7	252

These records indicate a rapid decline near the Fall line in all the landward wells and a marked prominence in the crystalline floor in the Middletown, Delaware, area, which may represent an extension of an axis from Iron, Chestnut, and Grays hills to the southeastward. They also show an actual thinning of the Potomac deposits to the seaward, as shown by the well at North End point, where the thickness of the Potomac beds is only one-half the normal thickness at the outcrop.

The record of the well borings becomes of the highest significance when it is remembered that this crystalline surface has been receiving along its seaward margin progressively greater and greater loading through deposition since Potomac time. The conclusion is readily reached that subsidence gradually took place, and that the land barrier along the eastern margin of the Potomac basin was depressed below sea-level.

Marsh and McGee, as well as most other writers, have expressed their belief in such a barrier, although without adducing any further concrete evidence of the same than the estuarine character of the Potomac sediments. McGee has suggested, as above stated, that the Potomac barrier may have been comparable in character and extent to the existing peninsula of Lower California.

Another possible, although perhaps less plausible, interpretation of these phenomena is found in the hypothesis of incipient folding in post-Potomac time.

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*The full sequence of Potomac deposits is not penetrated in the Baltimore, Farnhurst, Sandy Point, and Quantico wells.

Surface Configuration of Potomac Group and its possible Interpretation

The records of deep artesian well borings to the eastward of the Potomac belt indicate some clearly defined irregularities in the rate of decline of the Potomac surface. It will be seen from the following table that only a single record shows a greater decline than 25 feet, while most of them show a descent much less than this amount, in one instance (Crisfield) even less than the observed average landward dip (12½ feet) of the Eocene deposits which immediately overlie the Potomac beds to the southward.

Location of well.	Distance from point where Potomac surface reaches sealevel.	Depth of surface below tide level	Rate of descent in feet per mile.	Thickness of Potomac deposits.
	Miles.	*Feet.*	*Feet.*	*Feet.*
Middletown, Delaware	6	150±	25±	302±
Rock Hall, Maryland	7	240	34	Unknown
Claiborne, Maryland	19	440	23	"
Tunis Mills, Maryland	24	430	18	"
Tilghmans island, Maryland	27	400	15	"
Gloucester Court-House, Virginia	38	600	16	"
Williamsburg, Virginia	38	550±	14.5	276±
North End point, Virginia	62	920	15	252
Crisfield, Maryland	91	964	10.6	100+

According to these records, there is a marked lessening in the decline of the Potomac surface far to the seaward. There is even an actual rise in this surface in the "Eastern shore" of Maryland and Delaware between the Chester and Choptank rivers, although it again declines eastward a little farther seaward, as shown by the boring at Gloucester Court-House, Virginia. Whether we have to do with an erosional irregularity in the Potomac surface or with incipient deformation, the facts at hand do not permit us to determine. If the irregularity is due to the latter cause, the axis of the anticline would not seem to be coincident with that of the peninsula of Delaware, but would cross the latter in a northeast-southwest direction. A depressed barrier such as has

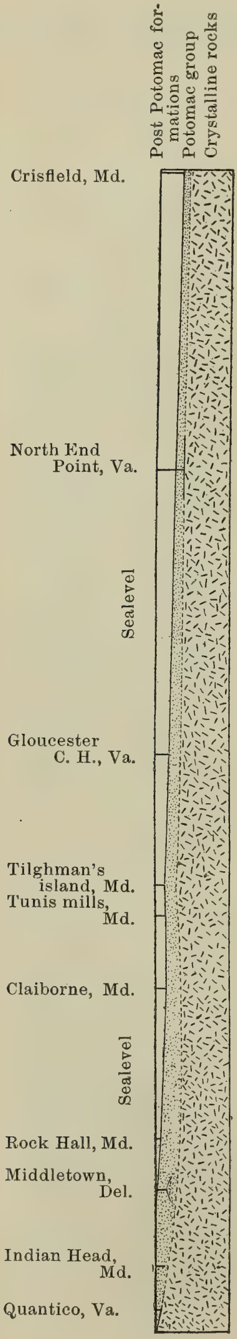
Post Potomac formations
Potomac group
Crystalline rocks
Crisfield, Md.
North End Point, Va.
Sealevel
Gloucester C. H., Va.
Tilghman's island, Md.
Tunis mills, Md.
Claiborne, Md.
Sealevel
Rock Hall, Md.
Middletown, Del.
Indian Head, Md.
Quantico, Va.

FIGURE 1.—*Generalized Vertical Section Across Atlantic Coastal Plain*
Showing Potomac Basin of Deposition

above been indicated may well have served as the seaward buttress in such deformation. Whether there may be more than one of these axial prominences in the Potomac surface is a question of much interest, but which can not be answered with the data at hand.

The lessening in the descent of the Potomac surface far to the seaward, as indicated by the borings at North End point and Crisfield, is in general in harmony with the relations of the subjacent crystalline floor above described.

AGE OF THE POTOMAC DEPOSITS

There has been much discussion as to the age of the Potomac group. Most geologists, particularly those who have studied the floras, have believed the entire group to be of Cretaceous age, while a few investigators, notably the late Professor Marsh,* of Yale University, have regarded it of Jurassic age. The authors of this paper in an earlier publication pointed out this difference of view, and clearly showed that the dicotyledonous floras were practically confined to the two upper formations, while the dinosaurs on which Professor Marsh based the Jurassic age of the Potomac group were found in the Arundel formation. As the result of these observations, and without attempting to decide finally regarding the paleontologic evidence, they placed the two lower formations of the Potomac group questionably in the Jurassic. Since the publication of the above paper the authors have made a very exhaustive examination of the several formations and collected large numbers of animal and plant remains. As the result of this work a considerable dicotyledonous flora has been found to exist in the Arundel, although

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*O. C. Marsh: "Jurassic Formation of the Atlantic Coast." Amer. Jour. Sci., Aug., 1896, pp. 105–115.

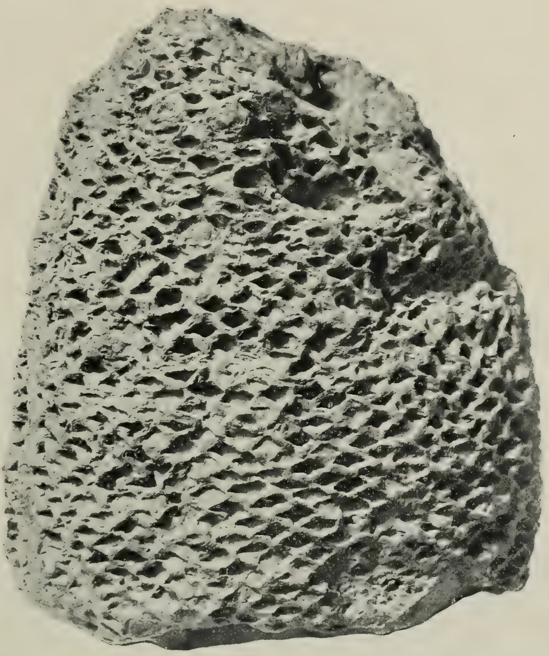


Figure 1.—Cycadeoidea marylandica (Font.) Cap. et Solms

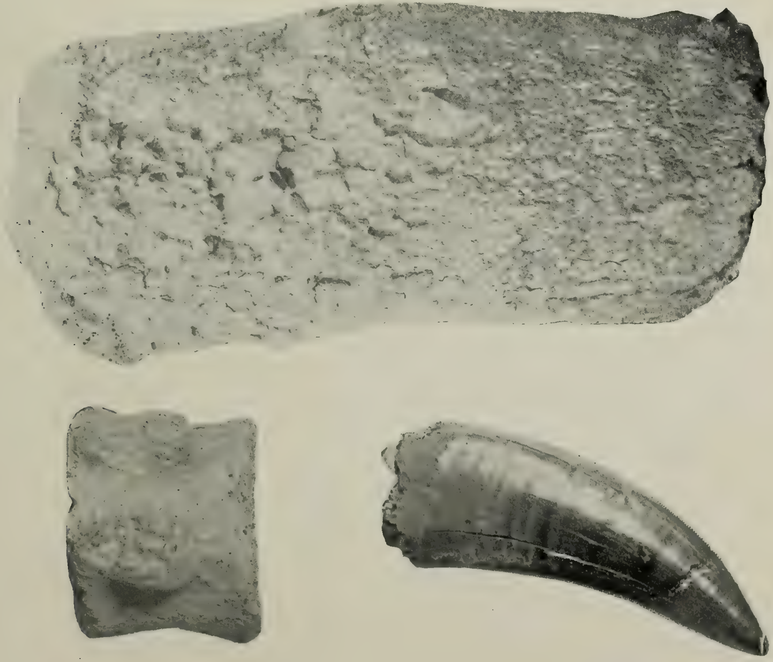


Figure 2.—Tooth, Vertebra, and Tibia of Allosaurus (?) sp.

FOSSILS FROM PATUXENT AND ARUNDEL FORMATIONS

of somewhat primitive type. At the same time a single dinosaurian bone, somewhat waterworn, and possibly redeposited from the Arundel, has been found in the Patapsco, although its fragmentary character renders it impossible to determine its systematic relations. The results of these observations, together with the discovery by the late Professor Cope of a plesiosaur in the Raritan formation of New Jersey and of a dinosaurian limb bone by Woolman in the Matawan formation of the same state, although not definitely settling the age of the deposits, cast further doubts on the Jurassic affinities of the Arundel and at the same time of the underlying formation—the Patuxent.

The question as to the age of the Potomac group is therefore narrowed down to two propositions:

First. Is the Arundel dinosaurian fauna conclusive evidence of the Jurassic age of that formation, and therefore of the subjacent Patuxent? No less an authority than Professor Marsh, after a study of its dinosaurian fauna, unquestionably refers the Potomac group to the Jurassic, although at the time not cognizant of the complexity of its deposits. He regarded the Potomac as a single formation, as has been the case with many other geologists. In his view regarding the Jurassic age of the Potomac, Professor Marsh has been supported by a few others, mostly among English geologists, since the question here presented is recognized to involve the age of the Wealden as well. Professor Marsh lays much stress on the equivalence of the Potomac with deposits which he has regarded as Jurassic in the Rocky Mountain district, but some doubts have been expressed by others whether these deposits may not be younger. It seems to the authors that further study by vertebrate paleontologists is required before these questions can be settled and the Jurassic age even of the two lower formations of the Potomac group can be accepted on the evidence of the fossil vertebrates.

Second. Are the floras of the Arundel and Patuxent formations, with their primitive dicotyledonous types, of necessity Cretaceous? There is apparently no question regarding the Cretaceous age of the Raritan and Patapsco formations, the uppermost beds of the Raritan even containing floras that have been regarded by Professor Ward as middle Cretaceous. The paleobotanists who have studied the floras of the earlier formations admit that there are many forms which show Jurassic affinities. Professor Fontaine, in his study of these floras, states that there was an "overwhelming percentage of Jurassic types," but unhesitatingly refers the Potomac flora as a whole to the Cretaceous, correlating the deposits with the Cretaceous beds of England. This view is held by nearly all paleobotanists who regard the presence of dicotyledons, although of primitive types, as unquestioned evidence of the Cretaceous age of the

Arundel and Patuxent formations. Further investigations of these floras may, to be sure, lead to other conclusions, but large collections have already been made, and the paleobotanists who have studied them have registered their decision regarding the Cretaceous age of the deposits in no uncertain way.

From our present knowledge of the floras and faunas it is apparent that there is considerable disparity between the evidence afforded by vertebrate paleontology and by paleobotany. At least such is the case if equal consideration is given the conclusions of each group of investigators. It seems essential, however, to suspend final decision of these questions until more exhaustive investigation of the faunas and floras has been made throughout the entire Coastal region. The authors therefore temporarily place the boundary line between the Jurassic and Cretaceous at the base of the Patapsco formation, but with the feeling that much doubt exists regarding it, and that the question is far from settled.

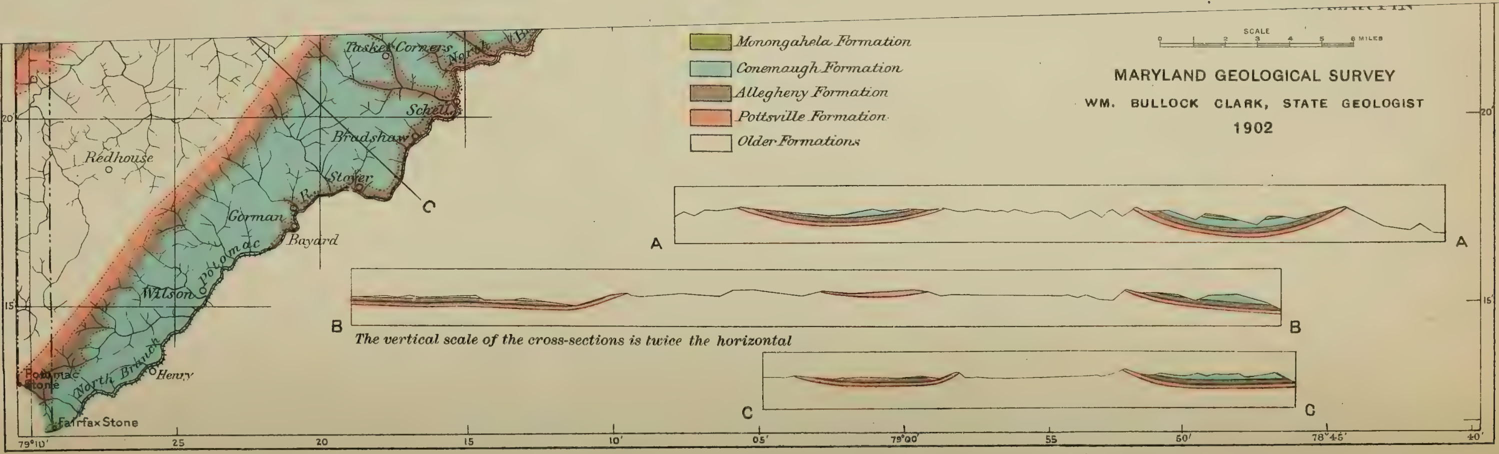
Study of scientific and economic Collections

A large number of new stations yielding fossil plants have been found by the authors, and the collections of silicified stems of Cycadeoidea (plate 28, figure 1) from the middle and lower Potomac have reached more than a hundred specimens. The collection of silicified and limonitized coniferous woods and lignites has likewise been much increased. A large dicotyledonous flora has also been collected from the upper formations. These materials are undergoing monographic study by Ward, Knowlton, and Fontaine.

One notable addition has been made to the collection of Arundel dinosauria—a rib of an exceptionally large dinosaur in a condition of preservation quite unusual in the Arundel beds. This bone, together with the large femur excavated in 1895 and a number of other fragments of huge bones and large teeth (plate 28, figure 2) found at widely separated stations, clearly show what has not been generally supposed, that gigantic as well as diminutive dinosauria inhabited the Arundel swamps. One of these, according to Lucas, who has undertaken the extremely difficult task of deciphering these mostly fragmentary remains, reached at least 40 feet in length.

Two localities in the Arundel of Maryland have yielded molluscan remains. These have been placed in the hands of Stanton for study.

Extensive collections illustrating the highly varied economic deposits of the Potomac terrane have also been made, notably of clays, whose study by Ries has already reached completion. The results of these several studies, as well as those of the authors, will later appear in monographs of the Maryland Geological Survey.


Monongahela Formation
Conemaugh Formation
Allegheny Formation
Pottsville Formation
Older Formations
SCALE
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MARYLAND GEOLOGICAL SURVEY
WM. BULLOCK CLARK, STATE GEOLOGIST
1902
Tasker Corners
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Schell
Bradshaw
Stoyer
R.
Gorman
Bayard
Potomac
Wilson
Redhouse
North Branch
Henry
Potomac Stone
Fairfax Stone
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A. Hoen & Co. Lith. Baltimore.

DISTRIBUTION OF THE COAL MEASURES OF MARYLAND

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 13, PP. 215-232 PLS. 29-39 JULY 29, 1902

CORRELATION OF THE COAL MEASURES OF MARYLAND

BY W. B. CLARK AND G. C. MARTIN

(*Read before the Society December 31, 1901*)

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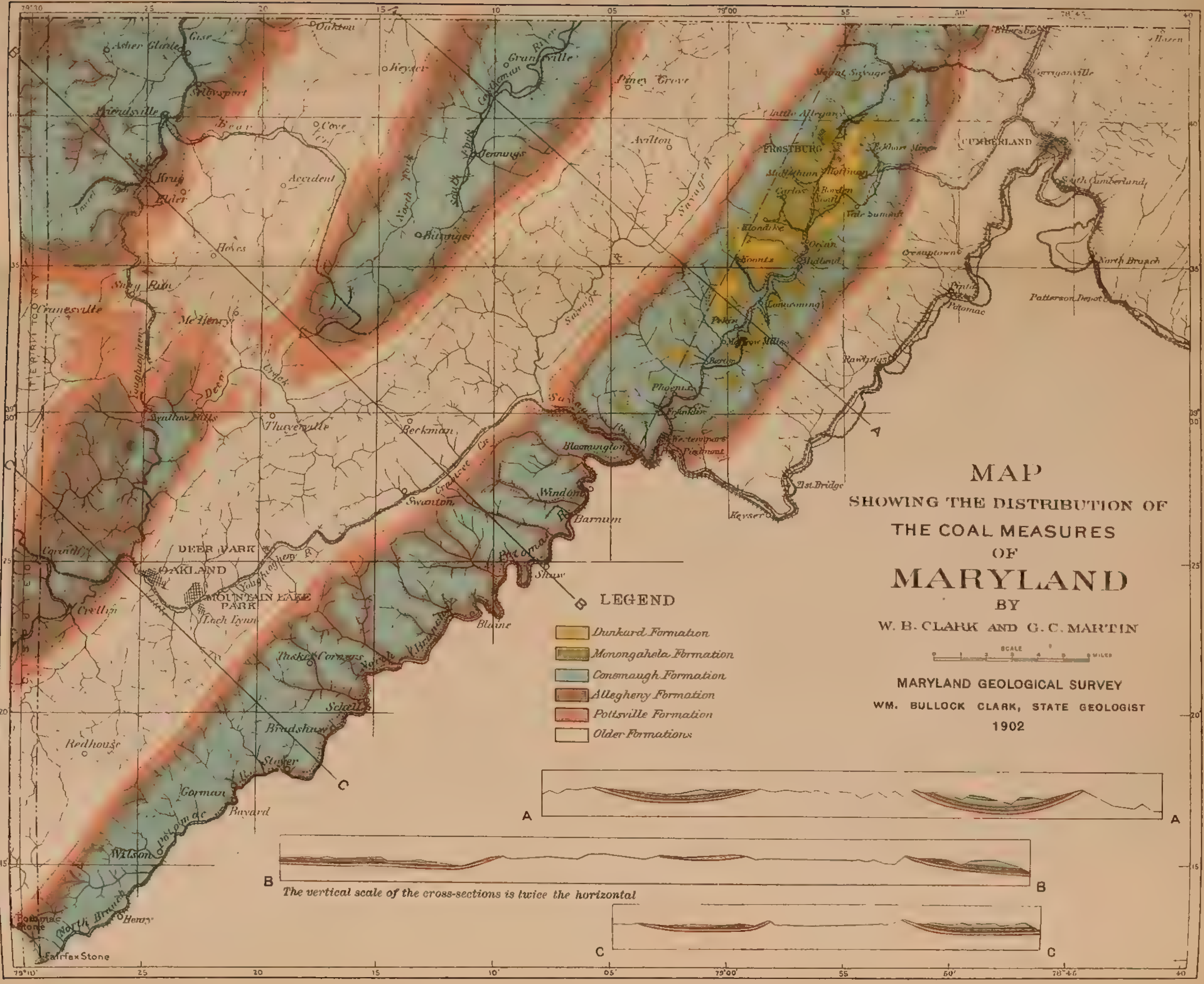
MAP
SHOWING THE DISTRIBUTION OF
THE COAL MEASURES
OF
MARYLAND
BY
W. B. CLARK AND G. C. MARTIN
SCALE
MILES
MARYLAND GEOLOGICAL SURVEY
WM. BULLOCK CLARK, STATE GEOLOGIST
1902
LEGEND
Dunkard Formation
Monongahela Formation
Conemaugh Formation
Allegheny Formation
Pottsville Formation
Older Formations
A
A
B
B
C
C
The vertical scale of the cross-sections is twice the horizontal
79°30
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Gise
Asher Glade
Selbysport
Friendsville
Keyser
Granville
Piney Grove
Cove
Jennings
Avilton
Accident
Krug
Hoyes
Bittinger
Sang Run
Cranesville
McHenry
Swallow Falls
Thayerville
Beckman
Swanton
DEER PARK
OAKLAND
MOUNTAIN LAKE PARK
Loch Lynn
Corinth
Crellin
Redhouse
Gorman
Bayard
Wilson
Henry
Fairfax Stone
Potomac Stone
Bradshaw
Stoyer
Schell
Tusker Corners
Blaine
Shaw
Barnum
Windom
Bloomington
Franklin
Westernport
Piedmont
Phoenix
Barton
Morrow Mills
Pekin
Lonaconing
Koontz
Midland
Ocean
Klondike
Vale Summit
Carlos
Borden Shaft
Midlothian
Mt. Savage
Little Allegany
FROSTBURG
Eckhart Mines
Moscow
CUMBERLAND
Corriganville
Ellerslie
Hazen
South Cumberland
North Branch
Patterson Depot
Cresaptown
Potomac
Rawlings
21st Bridge
Keyser
Savage R.
Youghiogheny R.
Potomac R.
North Branch
Deep Creek
Bear Cr.
Casselman R.
North Fork
South Fork
Crabtree Cr.
FAIRFAX LINE

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INTRODUCTION

The Coal Measures of Maryland have frequently been considered by geologists independently of the deposits of the same age in the adjacent states of Pennsylvania and West Virginia. This has been in large measure due to the fact that the study of the Maryland Coal Measures has been mainly confined to the Georges Creek basin, a deep synclinal trough that presents the only full representation of the formations of the Coal Measures within the limits of the state. The consequent lack of continuity in many of the coal seams of this basin with those of other regions in Maryland and adjacent states has led to the establishment of local terms in denominating these seams, with the result that much confusion exists as to their equivalents in the other areas. Even the relatively small amount of consideration hitherto given to the Garrett County basins has been chiefly confined to the local occurrences, without regard to the correlation of the seams with those of Pennsylvania and West Virginia.

The writers of this article have been engaged for several years in a study of the Coal Measures of Maryland, and are satisfied, both from an intimate comparison of the sequence of deposits found represented in Maryland with those of other areas, and from the continuity of certain of the beds with those of adjacent regions in Pennsylvania and West Virginia, that the same seams of coal, early described and named in Pennsylvania, West Virginia, and Ohio, are present in Maryland, and that these names must be accepted for the Maryland coalbeds. The accuracy of these conclusions is still further shown by a study of the floras and faunas, which at several horizons are highly distinctive, and prove the identity of many of the seams beyond all question. The authors have been very much impressed with the wide geographical range of the several members of the formations of the Coal Measures, many of the beds being traced without difficulty over thousands of square miles and for a great distance along the Appalachian unlift, with very little change in physical characteristics. The coalbeds especially show certain marked features that admit of their ready determination. This is seen both in the characteristic position of the partings, as well as in the physical constitution of the coal itself.

The Coal Measures of Maryland are divided into five formations, which from below upward are known as the Pottsville formation, the Allegheny formation, the Conemaugh formation, the Monongahela formation, and the Dunkard formation, the latter perhaps of Permian age.

The formations of the Coal Measures are limited to Allegany and Garrett counties, Maryland, the only full representation of formations being found in the Georges Creek basin of western Allegany and eastern Garrett counties. The upper Potomac basin, which is the southwesterly extension of the Georges Creek basin, lacks in its Maryland portion, except in two small areas, everything above the Conemaugh formation.

In the more western Castleman and upper and lower Youghiogheny basins the Pottsville, Allegheny, and Conemaugh alone are represented, the latter formation being only in part present. The Castleman basin contains, however, only a few rods north of the Pennsylvania line, the basal beds of the Monongahela formation.

The detailed description of the individual members of the Coal Measures series is presented in the succeeding pages. The grounds for the correlation of these several divisions of the Coal Measures of Maryland with the type sections of Pennsylvania and West Virginia are briefly given. The fuller discussion of this subject, together with the complete description of the floras and faunas found at the different horizons, will be presented in a forthcoming monograph of the Maryland Geological Survey on the Carboniferous formations of Maryland.

The Formations and their Equivalents

POTTSVILLE FORMATION

Composition and relations.—The strata here referred to the Pottsville formation consist of conglomerates, sandstones, shales, fire-clays, and coals which reach from 330 to 380 feet in thickness. The thickness is apparently greatest in the southeastern part of the region under discussion and decreases toward the north and west.

The Pottsville formation in Maryland is of the *western Pennsylvania type* and lacks the greatest thickness shown in the southern anthracite field of Pennsylvania, where the formation was named. Comparison of the formation, both as a whole as well as the individual members, with the strata exposed there can at present be made only on paleontological evidence. This is not at this time sufficient for complete correlation, and consequently the present discussion will be restricted to a consideration of the relations of the Maryland deposits with those exposed and named in western Pennsylvania. The U. S. Geological Survey in its Piedmont folio adopted the name Blackwater formation for the deposits of this horizon.

Basal contact (1).*—The Pottsville formation everywhere rests on the red and green shales and sandstones of the Mauch Chunk formation. There is some evidence which suggests an unconformity, but it is not as yet conclusive.

Sharon sandstone (2).—A sandstone which probably nowhere in Maryland exceeds 25 feet in thickness, and is sometimes absent, is generally

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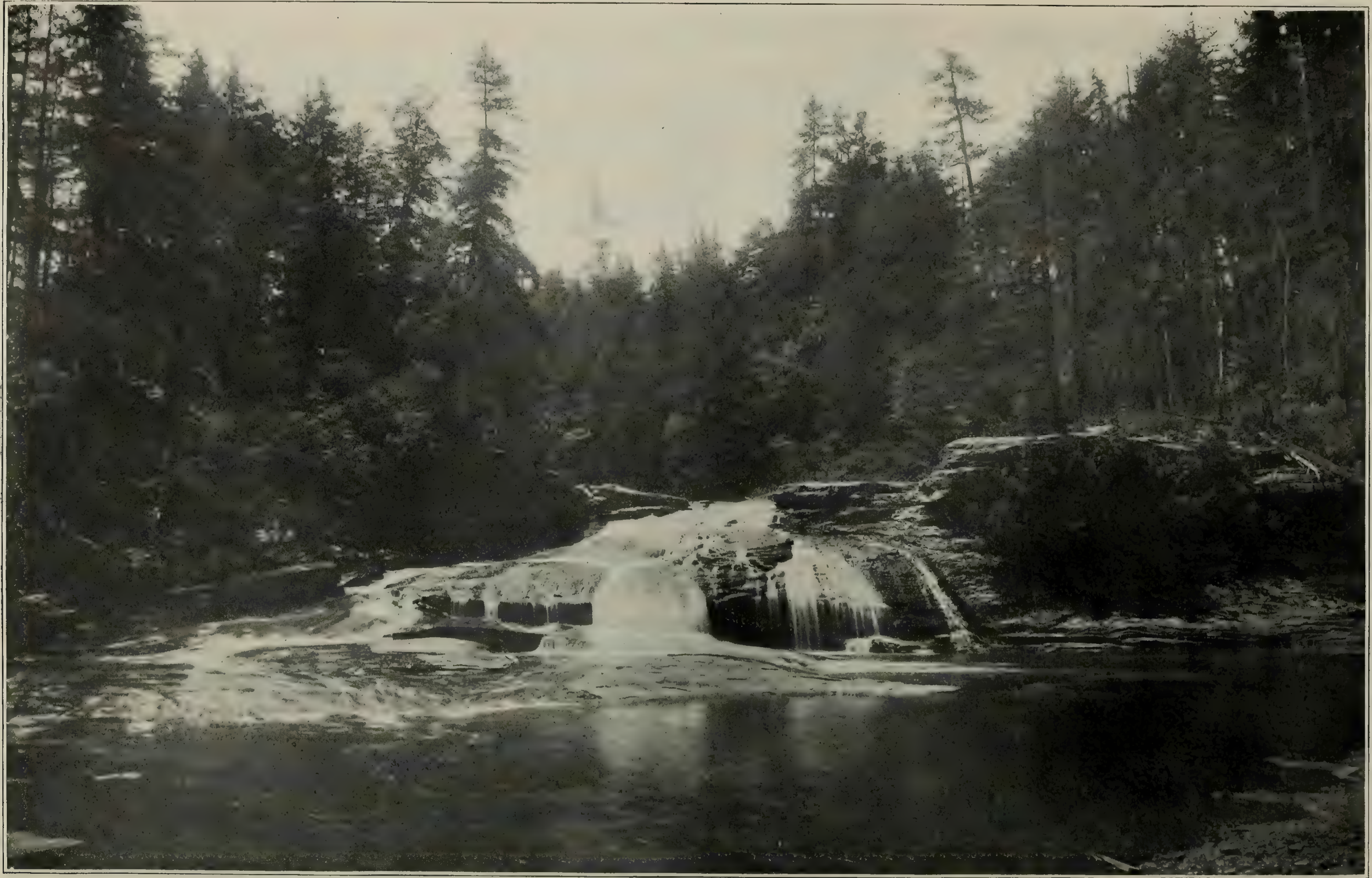
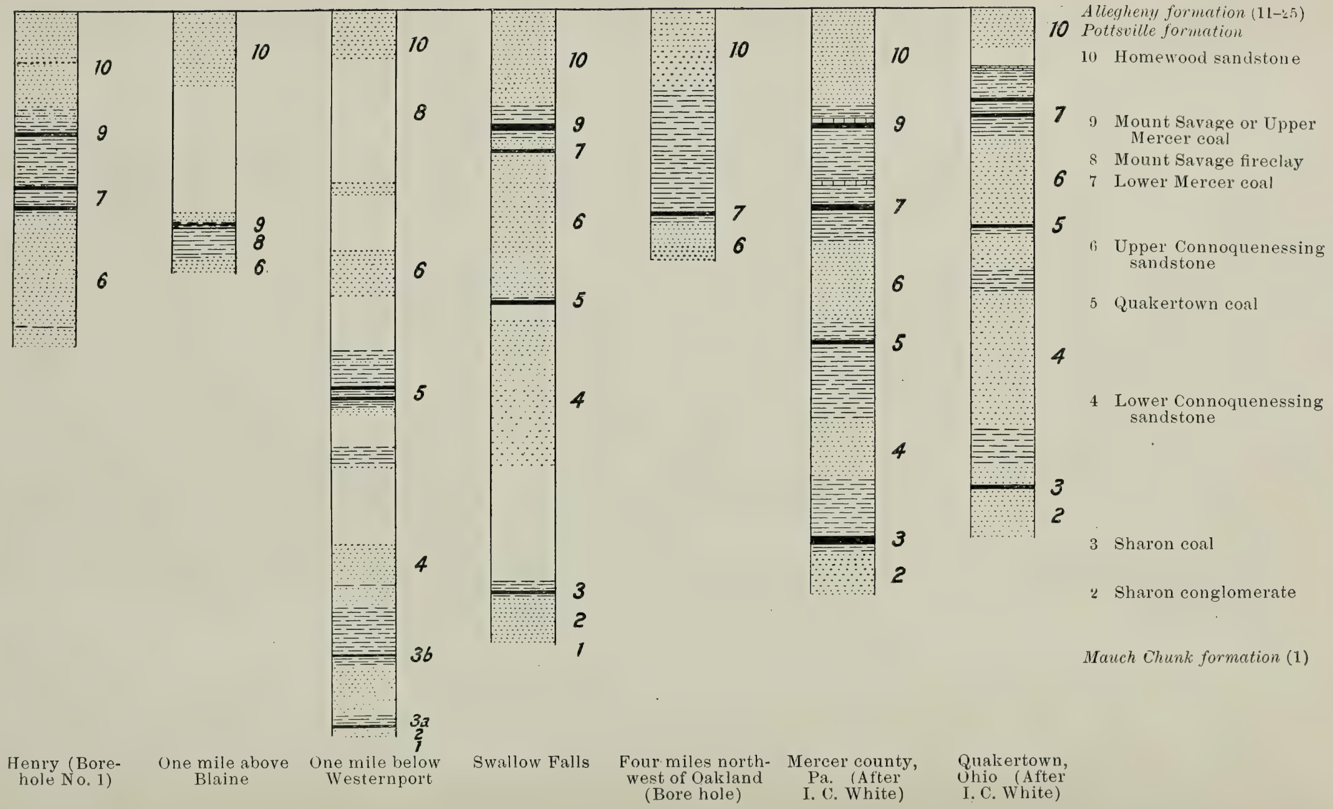
*The numbers used in this paper correspond to those used on the plates. There is no intention to give the coal seams and other members of the Coal Measures of Maryland a permanent *numbering*.



TOP OF UPPER CONNOQUENESSING SANDSTONE AT SWALLOW FALLS, YOUGHIOGHENY RIVER. POTTSVILLE FORMATION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Allegheny formation (11-25)
Pottsville formation
10 Homewood sandstone
9 Mount Savage or Upper Mercer coal
8 Mount Savage fireclay
7 Lower Mercer coal
6 Upper Connoquenessing sandstone
5 Quakertown coal
4 Lower Connoquenessing sandstone
3 Sharon coal
2 Sharon conglomerate
Mauch Chunk formation (1)
Henry (Bore-hole No. 1)
One mile above Blaine
One mile below Westernport
Swallow Falls
Four miles north-west of Oakland (Bore hole)
Mercer county, Pa. (After I. C. White)
Quakertown, Ohio (After I. C. White)

Scale: 1 inch = 100 feet

COLUMNAR SECTIONS OF THE POTTSVILLE FORMATION found at the base of the Pottsville formation. It is considered to represent the Sharon conglomerate because of its position conformably below the Sharon coal.

Sharon coal (3).—Good exposures of the strata at the base of the Pottsville are found one mile below Westernport, Allegany county, and in the gorge of the Youghiogheny river, below Swallow falls, Garrett county. At each of these localities there are beds of coal in a series of shales which lie between the sandstone above mentioned and a much thicker and more massive overlying sandstone. Both from the stratigraphic position and from the evidence* of the abundant fossil plants, these beds are regarded as the equivalent of the Sharon Coal group.

Lower Connoquenessing sandstone (4).—Overlying the shales of the Sharon group is a mass of very coarse, thick-bedded, white sandstone, which from its position is evidently the equivalent of the Lower Connoquenessing sandstone of Lawrence county, Pennsylvania.

Quakertown coal (5).—Near the top of the Lower Connoquenessing sandstone and overlain by a similar thick-bedded sandstone is a coal seam which corresponds in stratigraphic position to the Quakertown coal of Quakertown, Pennsylvania. The seam named the Bloomington coal † was assigned to a stratigraphic position corresponding to that of the Quakertown coal; but under this appellation were also included at a few points coals that are now known to belong to the Mount Savage and the Clarion seams.

Upper Connoquenessing sandstone (6).—Overlying the Quakertown coal is a coarse white sandstone about 75 feet in thickness, which corresponds to the Upper Connoquenessing sandstone described by Dr I. C. White, from Lawrence county, Pennsylvania.

Lower Mercer coal (7).—A very short distance above the top of the Upper Connoquenessing sandstone is a thin coal, which corresponds in its position with reference to the underlying and overlying beds to the Lower Mercer coal of western Pennsylvania.

Mount Savage fire-clay (8).—Above the Lower Mercer coal, or on top of the Connoquenessing sandstone when that coal is absent, is the Mount Savage fire-clay, so named from its typical development near the town of Mount Savage, Allegany county, Maryland. The bed consists of a mass of soft gray shale from 5 to 12 feet in thickness, which softens readily, on exposure to the weather, to a plastic, very refractory clay. As nodules in this mass, or replacing part or all of it, is the flint-clay, which differs from the plastic clay in not becoming plastic either by grinding or on exposure to the weather. The genetic difference between the two varieties is not known, and there seems to be no regularity in distribution between them.

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* Mr David White, after an examination of the fossils, has informed the authors that he considers them to belong to the horizon of the Sharon coal.

† The Physical Features of Allegany County, pp. 115, 170.

Mount Savage or Upper Mercer coal (9).—Immediately above the Mount Savage fire-clay is a seam of coal varying in thickness from 2 to 4 feet. It is the seam which has long been known as the Mount Savage coal in the northern end of the Georges Creek basin, and is the same as the Upper Mercer coal of Professor H. D. Rogers. The seam which was named the Westernport coal * in the southern Georges Creek basin is the same as this. The shales associated with this coal carry an abundant flora, which Mr David White, after examination, informs the authors to be identical with the Mercer flora.

Homewood sandstone (10).—A massive sandstone, varying in thickness from 30 to 100 feet, is found a short distance above the Mount Savage coal. This was formerly called the Piedmont sandstone. From its position between the Mercer coal group and the base of the Allegheny formation, it is evidently identical with the Homewood sandstone of Pennsylvania.

ALLEGHENY FORMATION

Composition and relations.—The Allegheny formation consists of a series of sandstones, shales, limestones, and coal seams having a total thickness in Maryland of from 260 to 350 feet. The thickness is greatest in the southern and eastern parts of the area, in this respect corresponding to the Pottsville.

The name "Allegheny series" was proposed by H. D. Rogers in 1840 † to include the strata from the lowest bed exposed at Pittsburg down to the " sandstones and conglomerate at the bottom of the coal formation." The type section is along the Allegheny river between Pittsburg and Warren. In later usage the formation was restricted by cutting off the upper part, which now constitutes the Conemaugh formation. The Allegheny formation was also known under the name of the Lower Productive Coal Measures or Lower Productive Measures. The U. S. Geological Survey in its Piedmont folio proposed the name Savage formation for the lower part of the Allegheny formation, including the Davis coal, and the name Bayard formation for the upper part of the Allegheny formation and lower part of the Conemaugh formation up to and including the Four-foot coal of the Potomac valley.

Brookville coal (11).—A seam of coal varying from 1 to 4 feet in thickness sometimes occurs at or very near the base of the Allegheny forma-

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* The Physical Features of Allegany County, pp. 115, 170, 171.

† Fourth Annual Report of the Geological Survey of the State of Pennsylvania, p. 150.

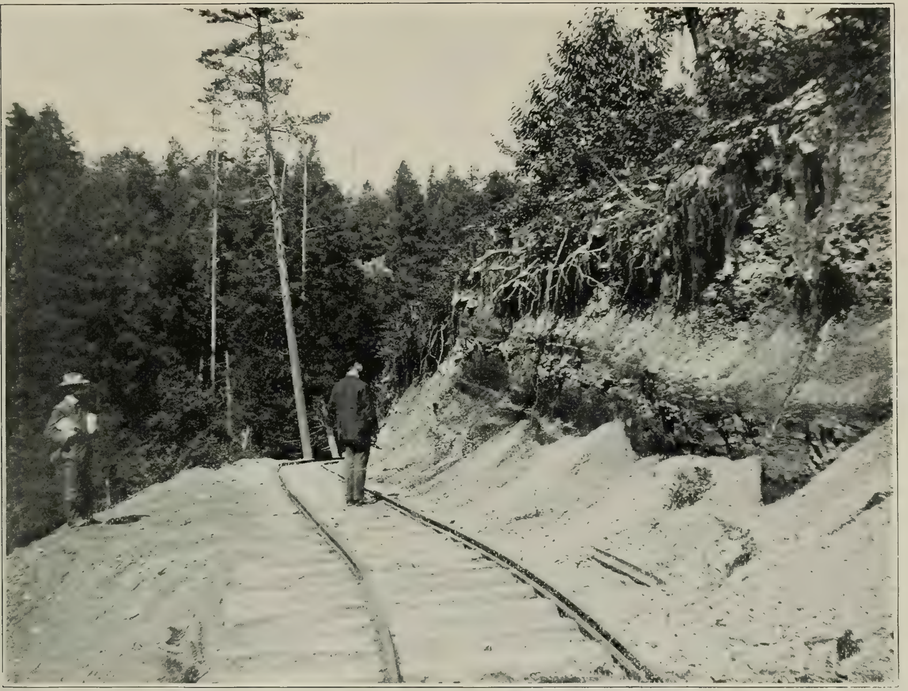


Figure 1.—Mount avage Coal, Swallow Falls, Youghiogheny River

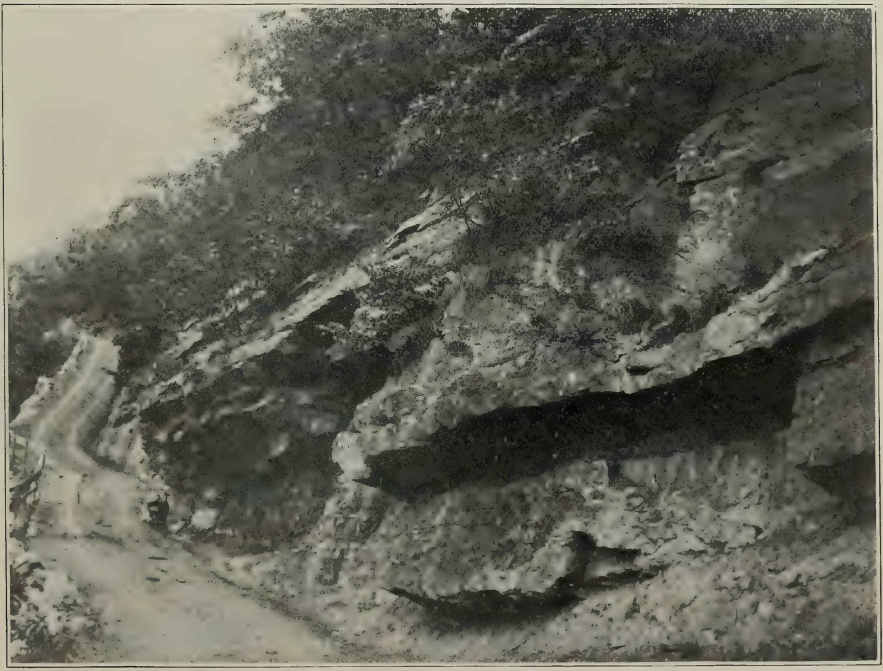
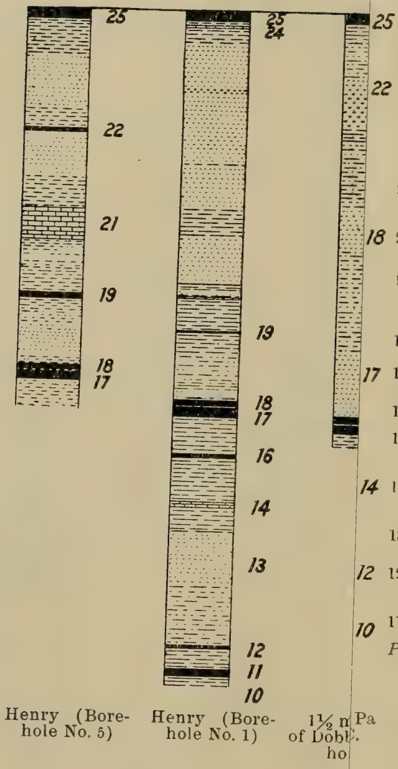


Figure 2.—Contact of Pottsville and Mauch Chunk, near Westernport

POTTSVILLE FORMATION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Henry (Bore-hole No. 1)
1½ m Pa
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ho

Conemaugh formation (26–44)

Allegheny formation

25 Upper Freeport coal

24 Upper Freeport limestone (Bolivar fire-clay)

23 Upper Freeport sandstone

22 Lower Freeport coal

21 Lower Freeport limestone

20 Lower Freeport sandstone

19 Upper Kittanning coal

18 Middle Kittanning coal

17 Lower Kittanning coal

16 "Split-six" coal

15 Kittanning sandstone

14 Ferriferous limestone

13 Clarion sandstone

12 Clarion coal

11 Brookville coal

Pottsville formation (1–10)

tion. This is in the stratigraphic position of the Brookville coal. It has been known in Maryland as the Bluebaugh coal, and was so called in the Report on the Geology of Allegany County.

Clarion coal (12).—A seam of coal approximating 2½ feet in thickness is found at an interval of from 12 to 30 feet above the Brookville coal, or, in the absence of that coal, about the same distance above the base of the formation. This seam corresponds in position to the Clarion coal. It has been hitherto known in Maryland as the Parker coal, and was so called in the Report on the Geology of Allegany County.

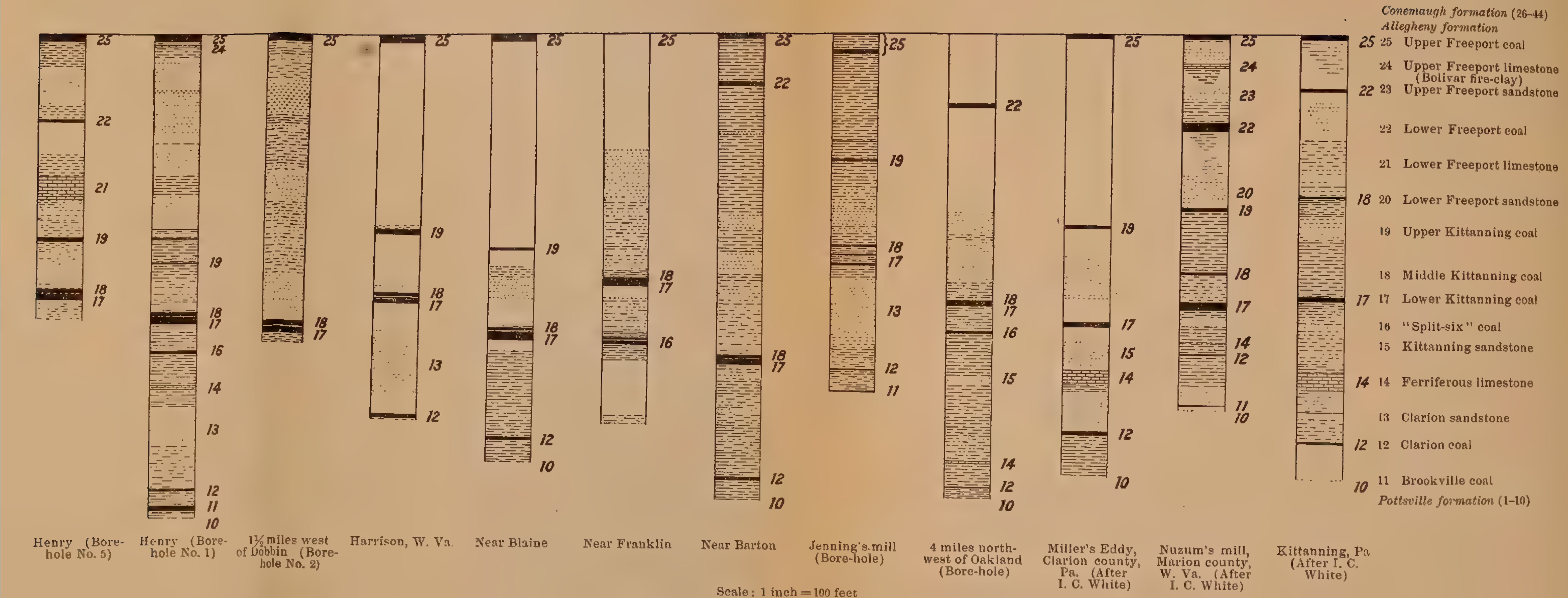
Clarion sandstone (13).—Separated from the Clarion coal by a thin series of shales, there is frequently a massive sandstone, which sometimes reaches as much as 70 feet in thickness. It is especially well developed along the Potomac river in Garrett county, where it can readily be mistaken for the Homewood sandstone. This sandstone is in the stratigraphic position and has the lithologic character of the Clarion sandstone of Pennsylvania.

Ferriferous limestone (14).—A short distance above the Clarion sandstone, or the horizon for it, is a limestone a few feet in thickness. This limestone has been seen at only a few points in the southern part of Garrett county. At all of these localities it is evidently of fresh-water origin, and contains no fossils except Ostracoda. In the bore-hole four miles northwest of Oakland a thin limestone with marine fossils was encountered at this horizon. It is the position of the "Ferriferous" limestone of Pennsylvania, and is probably the equivalent of the Putnam Hill limestone of Zanesville, Ohio.

Kittanning sandstone (15).—The interval between the Ferriferous limestone and the next coal above is usually occupied by shale. In the bore-hole four miles northwest of Oakland, where this interval is large, it is occupied in part, however, by sandstone. This sandstone corresponds in position to the Kittanning sandstone of Pennsylvania.

"*Split-six*" *coal* (16).—Separated from the Ferriferous limestone by a variable thickness of shale is a seam of coal about 4 feet in thickness, but too impure to mine. This is best developed in the southern end of the Georges Creek valley, where it is known as the "Split-six." It does not appear to have any named equivalent in other regions.

Lower Kittanning coal (17).—A seam of coal of great persistence, which can be seen at almost every point where strata of this horizon are exposed, occurs at an interval of from 90 to 140 feet above the base and from 170 to 210 feet below the top of the Allegheny formation. This seam corresponds in stratigraphic position to the Lower Kittanning coal of Pennsylvania.


Conemaugh formation (26–44)
Allegheny formation
25 Upper Freeport coal
24 Upper Freeport limestone (Bolivar fire-clay)
23 Upper Freeport sandstone
22 Lower Freeport coal
21 Lower Freeport limestone
20 Lower Freeport sandstone
19 Upper Kittanning coal
18 Middle Kittanning coal
17 Lower Kittanning coal
16 "Split-six" coal
15 Kittanning sandstone
14 Ferriferous limestone
13 Clarion sandstone
12 Clarion coal
11 Brookville coal
Pottsville formation (1–10)
Henry (Bore-hole No. 5)
Henry (Bore-hole No. 1)
1⅜ miles west of Dobbin (Bore-hole No. 2)
Harrison, W. Va.
Near Blaine
Near Franklin
Near Barton
Jenning's mill (Bore-hole)
4 miles north-west of Oakland (Bore-hole)
Miller's Eddy, Clarion county, Pa. (After I. C. White)
Nuzum's mill, Marion county, W. Va. (After I. C. White)
Kittanning, Pa (After I. C. White)

Scale: 1 inch = 100 feet

COLUMNAR SECTIONS OF THE ALLEGHENY FORMATION

Middle Kittanning coal (18).—Another seam of equal persistence is found at a distance of from a few inches to 30 feet above the top of the Lower Kittanning coal. Over broad areas it is so close to the Lower Kittanning that the two form practically one seam. The upper of these closely associated seams is probably the equivalent of the Middle Kittanning coal of Pennsylvania.

The Lower and Upper Kittanning coals are called in the upper Potomac basin the Davis coal, and locally in the lower Georges Creek basin and in the vicinity of Piedmont, West Virginia, by the name of the "Six-foot."

Upper Kittanning coal (19).—Separated from the Middle Kittanning coal by from 30 to 60 feet of shale and sandstone is a seam of coal from 1 to 3½ feet in thickness. This is in the position of the Upper Kittanning coal.

Lower Freeport sandstone (20).—A short distance above the Upper Kittanning coal is a massive sandstone of variable thickness, which corresponds in position to the Lower Freeport sandstone.

Lower Freeport limestone (21).—A limestone 16 feet in thickness was encountered at a distance of 28 feet above the Upper Kittanning coal in one of the bore-holes at Henry. This is the horizon of the Lower Freeport limestone of Pennsylvania. This limestone has not been seen elsewhere in Maryland.

Lower Freeport coal (22).—A seam of coal of variable thickness sometimes appears at a distance of from 35 to 60 feet below the top of the Allegheny formation. It corresponds in position to the Lower Freeport coal of Pennsylvania.

Upper Freeport sandstone (23).—A short distance above the Lower Freeport coal is a very massive, sometimes conglomeritic, sandstone. This is the Upper Freeport sandstone of Pennsylvania.

Upper Freeport limestone and Bolivar fire-clay (24).—Immediately above the Upper Freeport sandstone, or the horizon of that sandstone, there sometimes appears a thin limestone which corresponds in position with the Upper Freeport limestone. At several places a flint fire-clay has been observed at this horizon, and in such cases the limestone is absent. A similar relationship has been reported from Pennsylvania, where the Bolivar fire-clay is regarded as "replacing" the Lower Freeport limestone.

Upper Freeport coal (25).—At the top of the Allegheny formation is a very persistent seam of coal, which, in its relationships to the overlying and underlying strata, corresponds to the Upper Freeport coal of Pennsylvania. This seam has been called the "Four-foot" in the Georges Creek valley and the "Three-foot" in the Potomac valley. In the Pied-

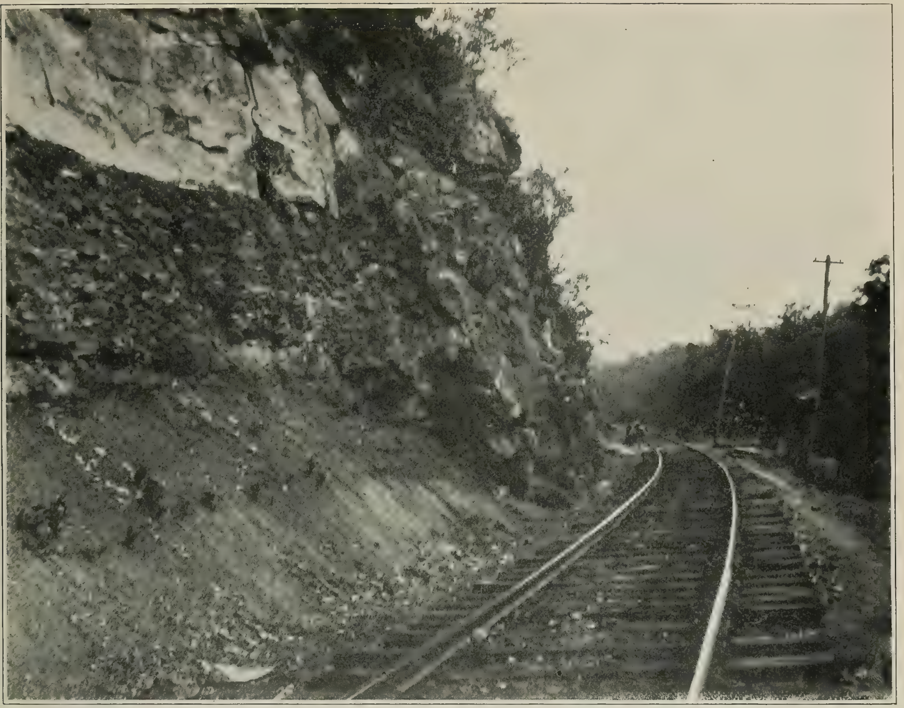


FIGURE 1.—CLARION SANDSTONE, SHALE, AND COAL, NEAR SHAW

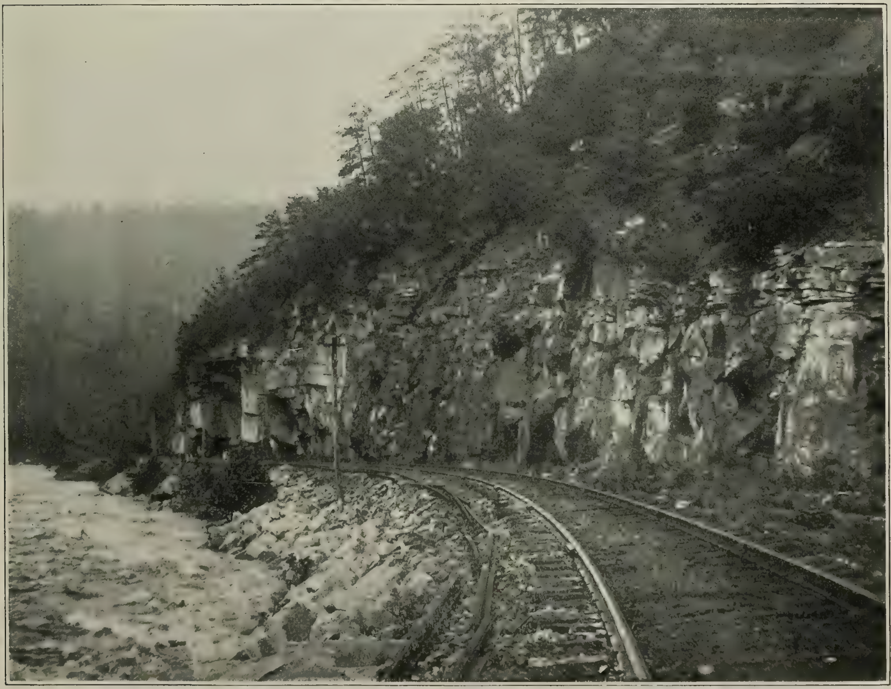
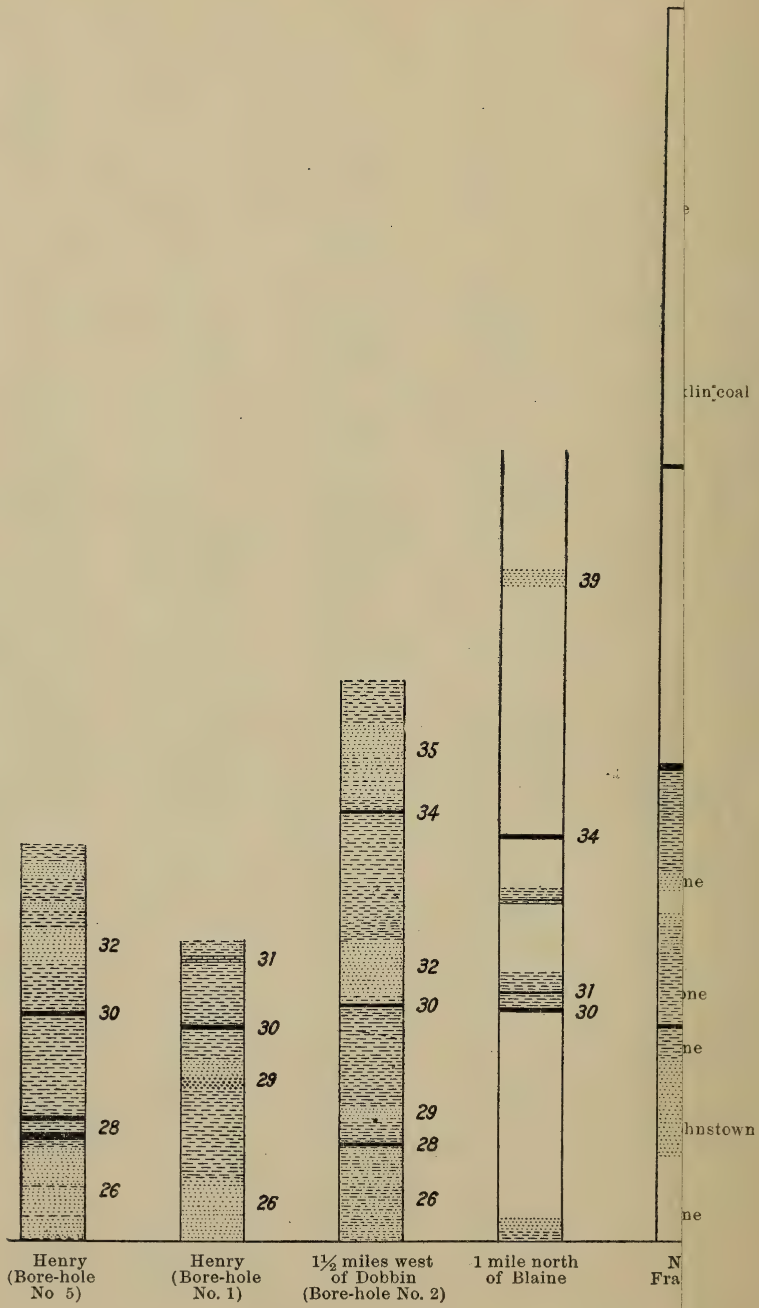


FIGURE 2.—CLARION SANDSTONE, NEAR WINDOM

ALLEGHENY FORMATION


Henry (Bore-hole No 5)
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mont folio of the U. S. Geological Survey and the "Report on the Geology of Allegany County" it is called the Thomas coal.

CONEMAUGH FORMATION

Composition and relations.—The strata here referred to the Conemaugh formation consist of a series of sandstones, shales, conglomerates, limestones, and coal seams. The total thickness varies from 600 to 700 feet. The average thickness in the Georges Creek basin is about 630 feet. In the Potomac basin it is slightly greater. In the Castleman basin the only complete measurement obtainable in Maryland gave about 700 feet, which, however, is 100 feet in excess of the thickness obtained by the Pennsylvania survey farther north in the same basin. The thickness in the lower Youghiogheny basin is slightly over 600 feet.

This formation, generally known hitherto under the name of the Lower Barren Coal Measures, or Lower Barren Measures, was called the Conemaugh formation by Franklin Platt in 1875 * from the typical development of these rocks along the Conemaugh river, in western Pennsylvania. This formation has also been known under the name of the Pittsburg Coal series and the Elk River series, while that portion above the Four-foot coal of the Potomac valley was called by the U. S. Geological Survey in its Piedmont folio the Fairfax formation.

Lower Mahoning sandstone (26).—A very massive and persistent sandstone from 25 to 50 feet in thickness occurs at the base of the Conemaugh formation. It corresponds to the lower part of the Mahoning sandstone of western Pennsylvania and eastern Ohio.

Mahoning limestone (27).—Overlying the Lower Mahoning sandstone is sometimes a bed of limestone corresponding to the Mahoning limestone. It has been recorded by I. C. White † from a bore-hole at Fairfax, where it has a thickness of 20 feet, and occurs at a distance of 42 feet above the base of the formation. In the bore-hole at Jennings mill, in the Castleman basin, it is apparently represented by a bed of carbonate of iron 3 feet in thickness and is about 20 feet above the base of the formation. This corresponds to the Johnstown iron ore, which, in Pennsylvania, is recognized as occurring at the horizon of the Mahoning limestone.

Mahoning coal (28).—In the absence of the Mahoning limestone there frequently appears in its place a thin seam of coal, known in Pennsylvania and West Virginia as the Mahoning coal.

Upper Mahoning sandstone (29).—Immediately above the Black roof-shales of the Mahoning coal, or, in the absence of the coal or of the lime-

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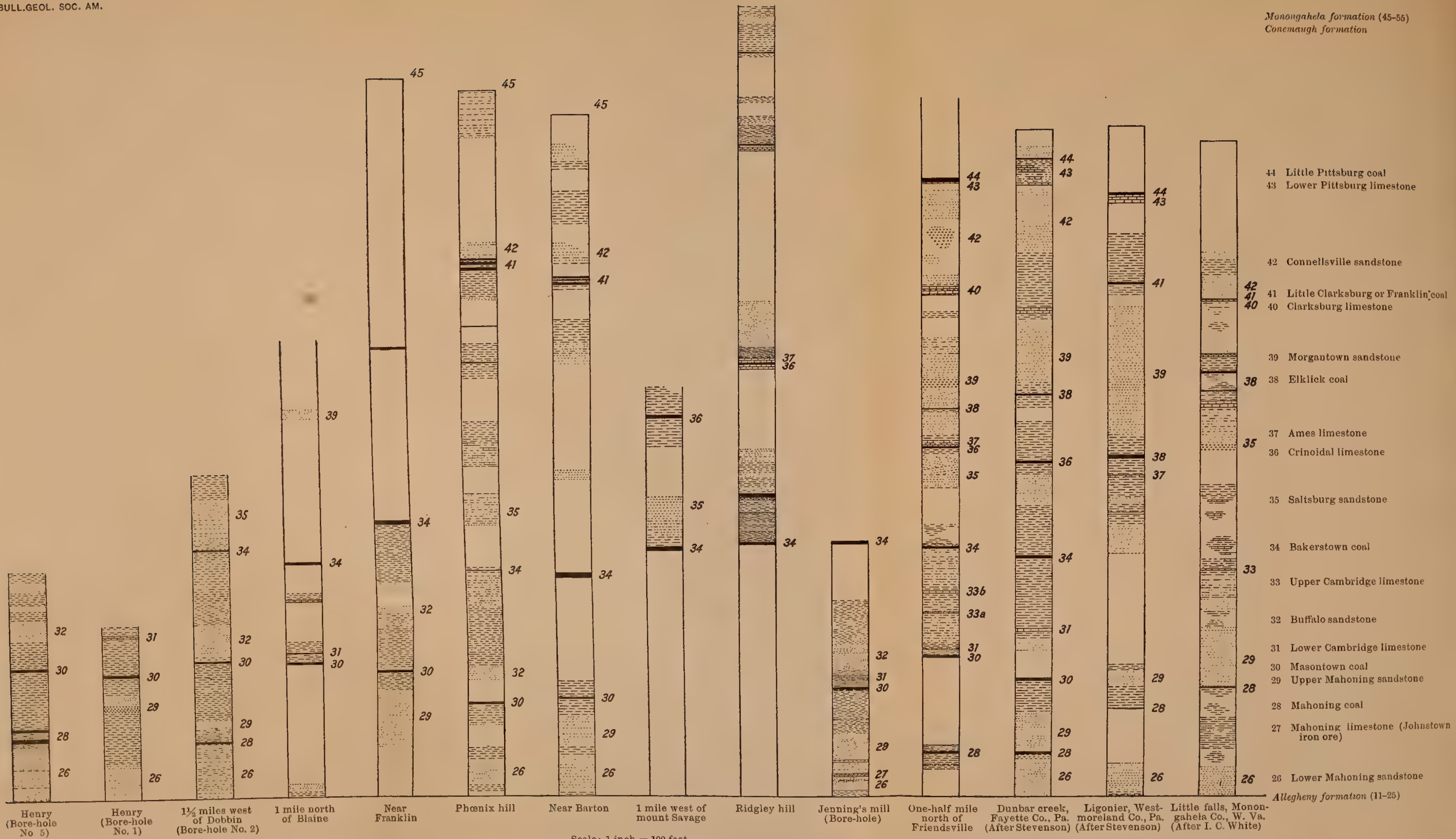
* Second Geological Survey of Pennsylvania, H, p. 8.

† Bull. 65, U. S. Geol. Survey, p. 82.


Monongahela formation (45–55)
Conemaugh formation
44 Little Pittsburg coal
43 Lower Pittsburg limestone
42 Connellsville sandstone
41 Little Clarksburg or Franklin coal
40 Clarksburg limestone
39 Morgantown sandstone
38 Elklick coal
37 Ames limestone
36 Crinoidal limestone
35 Saltsburg sandstone
34 Bakerstown coal
33 Upper Cambridge limestone
32 Buffalo sandstone
31 Lower Cambridge limestone
30 Masontown coal
29 Upper Mahoning sandstone
28 Mahoning coal
27 Mahoning limestone (Johnstown iron ore)
26 Lower Mahoning sandstone
Allegheny formation (11–25)
Henry (Bore-hole No. 5)
Henry (Bore-hole No. 1)
1½ miles west of Dobbin (Bore-hole No. 2)
1 mile north of Blaine
Near Franklin
Phœnix hill
Near Barton
1 mile west of mount Savage
Ridgley hill
Jenning's mill (Bore-hole)
One-half mile north of Friendsville
Dunbar creek, Fayette Co., Pa. (After Stevenson)
Ligonier, Westmoreland Co., Pa. (After Stevenson)
Little falls, Monongahela Co., W. Va. (After I. C. White)

Scale: 1 inch = 100 feet

COLUMNAR SECTIONS OF THE CONEMAUGH FORMATION

stone, as the case may be, forming one continuous mass with the Lower Mahoning sandstone, is the Upper Mahoning sandstone. This sandstone varies much in lithologic character and thickness. Sometimes it is very massive and conglomeritic, while at other times it is thin-bedded and shaly.

Masontown coal (30).—A seam of coal having a thickness of from 18 to 24 inches, and without partings, is found in a position varying from 85 to 125 feet above the base of the formation. From its position above the Mahoning sandstone, and more especially from its relation to the overlying fossiliferous beds, this is regarded as the equivalent of the Masontown coal of Pennsylvania.

Lower Cambridge limestone (31).—Separated from the Masontown coal by about 5 feet of fissile, black carbonaceous shale is a band of calcareous shale or bituminous limestone, usually about 8 inches in thickness. This limestone and the overlying shales are filled with well preserved marine fossils. The fauna is very rich, both in individuals and in species. No detailed study has as yet been made of it, but enough species have been determined to make it certain that it is the fauna of the Lower Cambridge limestone of Ohio and Pennsylvania. The greatest thickness of this limestone known in Maryland was obtained in the bore-hole at Jennings mill. Here it is 3 feet thick, and is overlaid by 4 feet of black, fossiliferous shale.

Buffalo sandstone (32).—A short distance above the Lower Cambridge limestone is a sandstone, which sometimes attains a thickness of 40 feet. It corresponds with the Buffalo sandstone of western Pennsylvania, which was formerly considered to be the equivalent of the Upper Mahoning sandstone, but which I. C. White has shown to overlie the Lower Cambridge limestone.

Upper Cambridge limestone (33).—In the river bluff north of Friendsville there are two thin limestone beds at intervals of 32 and 50 feet respectively above the Lower Cambridge limestone. One or both of these probably represent the Upper Cambridge limestone of Ohio. Both beds carry marine fossils.

Lower red shales.—The interval between the top of the Buffalo sandstone and the under clay of the Bakerstown coal contains a large amount of red and green shale. The Upper Cambridge limestones occur in these shales, and the red shales themselves carry fossils. These red beds are very persistent, and their outcrop can be easily traced throughout the Lower Youghiogheny basin. They were encountered at their normal position in the bore-hole at Jennings mill, in the Castleman basin, and are evidently the beds known by that name in Pennsylvania.

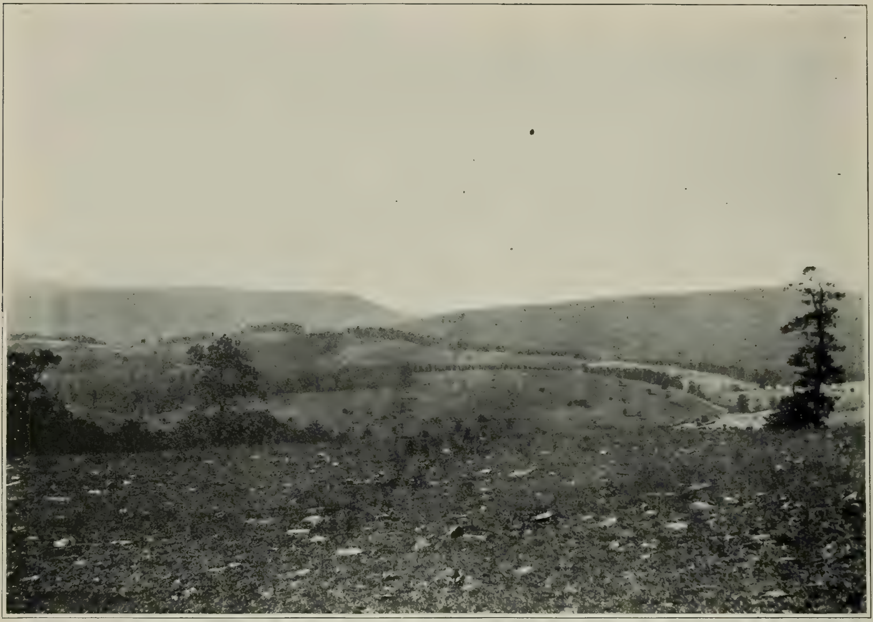


Figure 1.—Conemaugh Topography, with Pottsville Ridges in Background, Northwest of Westernport

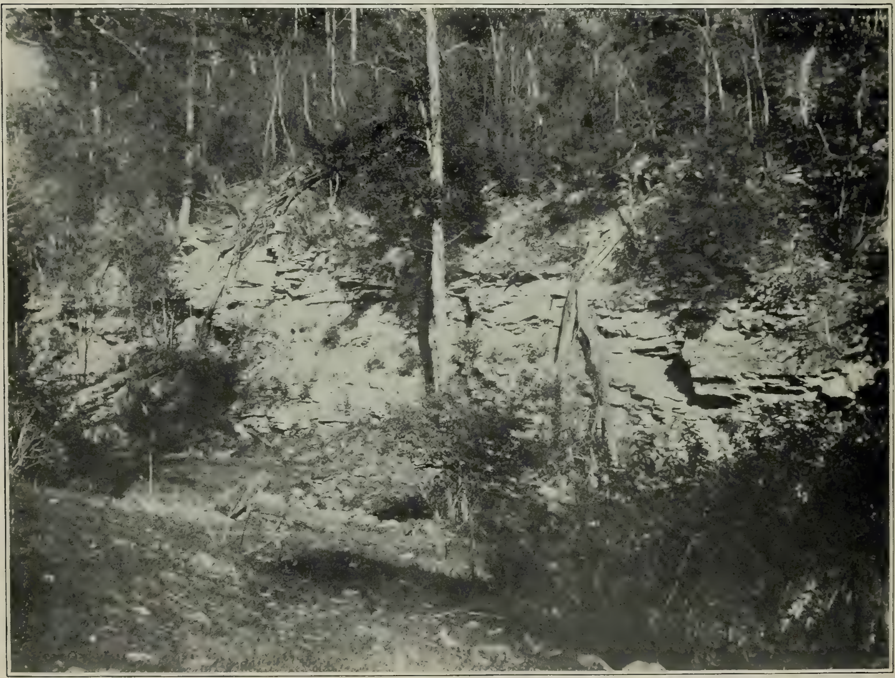


Figure 2.—Morgantown Sandstone near Lonaconing

CONEMAUGH FORMATION

Bakerstown coal (34).—A very persistent seam, which in some districts is of considerable economic importance, occurs at an interval varying from 90 to 135 feet above the Masontown coal. The thickness of the coal varies from 2 to 5 feet. This seam occupies the stratigraphic position of the Bakerstown coal of Pennsylvania. It is the locally recognized Barton coal, described by that name in the Report on the Geology of Allegany County, but apparently not the Barton coal of the Pennsylvania reports. In the Georges Creek basin it is commonly known as the "Three-foot," in the Potomac valley as the "Four-foot," and in the Castleman valley as the "Honeycomb" seam.

Saltsburg sandstone (35).—A massive crossbedded sandstone, about 30 feet in thickness, occurs above the Bakerstown coal and is separated from it by a variable thickness of shale. This sandstone is evidently the Saltsburg sandstone of Professor Stevenson, so named from its occurrence at Saltsburg, Pennsylvania.

Crinoidal coal (36).—A thin but very persistent and characteristic coal seam, which has been of the greatest service in correlation, is found at an interval of from 90 to 160 feet above the Bakerstown coal. This seam is the same as the one which has been called the "Crinoidal coal" in the Pennsylvania reports and the "Crinoidal coal" or "Coal 8*b*" in the Ohio reports. It is possible also that the "Platt coal" of the Somerset basin may be the same as the "Crinoidal." The coal is well exposed and has been mined for local use at several places in the Castleman basin and in the Lower Youghiogheny basin near Friendsville, and also at many places in the northern end of the Georges Creek basin, where it attains the thickness of 28 inches, the greatest known in Maryland. One of these old mines near Mount Savage was visited by Lyell in 1842, who described the occurrence of the coal, its position and thickness, and gave a list of fossils found in the overlying shales.*

Ames or Crinoidal limestone (37).—The Crinoidal coal is overlain by either a limestone or a calcareous shale full of marine fossils. This limestone occurs in a position exactly similar, with reference to the overlying and underlying strata, to that of the Crinoidal limestone of the Pennsylvania reports, and to the Ames limestone of the Ohio reports. The fauna, as far as known, is the same as that found in this bed in Ohio and Pennsylvania. In both of these states and in West Virginia the limestone is of very great persistence and has been of the greatest service in the correlation and location of the coals.

Elklick coal (38).—A very thin and variable coal, which apparently represents the Elklick coal of Pennsylvania and West Virginia, is found at about 35 feet above the Ames limestone.

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* Travels in North America, with Geological Observations on the United States, Canada, and Nova Scotia.

Morgantown sandstone (39).—Immediately above the Elklick coal or its horizon, if the coal is absent, is a very massive and constant sandstone, frequently conglomeritic in part, which corresponds exactly in its stratigraphic relations with the Morgantown sandstone, so called from its typical development at Morgantown, West Virginia.

Clarksburg limestone (40).—A short distance above the top of the Morgantown sandstone is a limestone from 3 to 9 feet in thickness. This limestone has a rather characteristic appearance and contains abundant fossil fish and Ostracoda. Marine fossils are entirely absent. In its stratigraphic position, its lithologic characteristics, and the general nature of its fauna this limestone corresponds to the Clarksburg limestone, so called from its occurrence at Clarksburg, West Virginia.

Franklin or Little Clarksburg coal (41).—A seam of coal which is identical with the Little Clarksburg coal of Dr I. C. White is found immediately above the Clarksburg limestone. In the Georges Creek basin this coal is popularly called the "Dirty-nine-foot," and in the Report on the Geology of Allegany County it was named the Franklin coal from its occurrence near the town of Franklin.

Connellsville sandstone (42).—A short distance above the Franklin coal is a very prominent sandstone of considerable thickness. It is very strongly developed in the Georges Creek and Potomac basins, where it has a very marked influence on the topography. This sandstone is found in the stratigraphic position of the Connellsville sandstone of southwestern Pennsylvania.

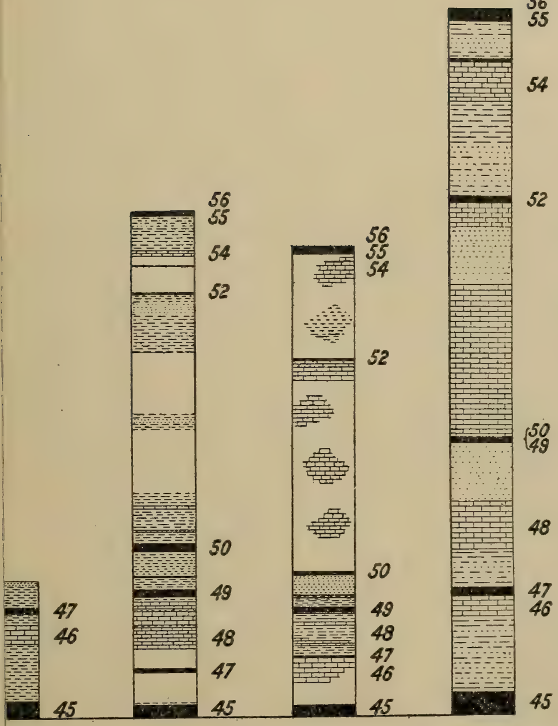
Lower Pittsburg limestone (43).—Almost immediately above the Connellsville sandstone is a thin limestone containing no fossils except Ostracoda, as far as observed. It has all the characteristic features and is evidently the Lower Pittsburg limestone.

Little Pittsburg coal (44).—Immediately above the last-mentioned limestone and from 50 to 90 feet below the top of the formation is a seam of coal from 1 to 3 feet in thickness. This is the equivalent of the Little Pittsburg coal of Pennsylvania.

MONONGAHELA FORMATION

Composition and relations.—The strata composing the Monongahela formation in Maryland consist of a series of shales, sandstones, limestones, and coal seams. The thickness varies from 240 to 260 feet. The formation is entirely restricted in Maryland to the Georges Creek-Potomac basin. The name "Monongahela series" was proposed by

Dunkard formation (56–61)
Monongahela formation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on, Pa.

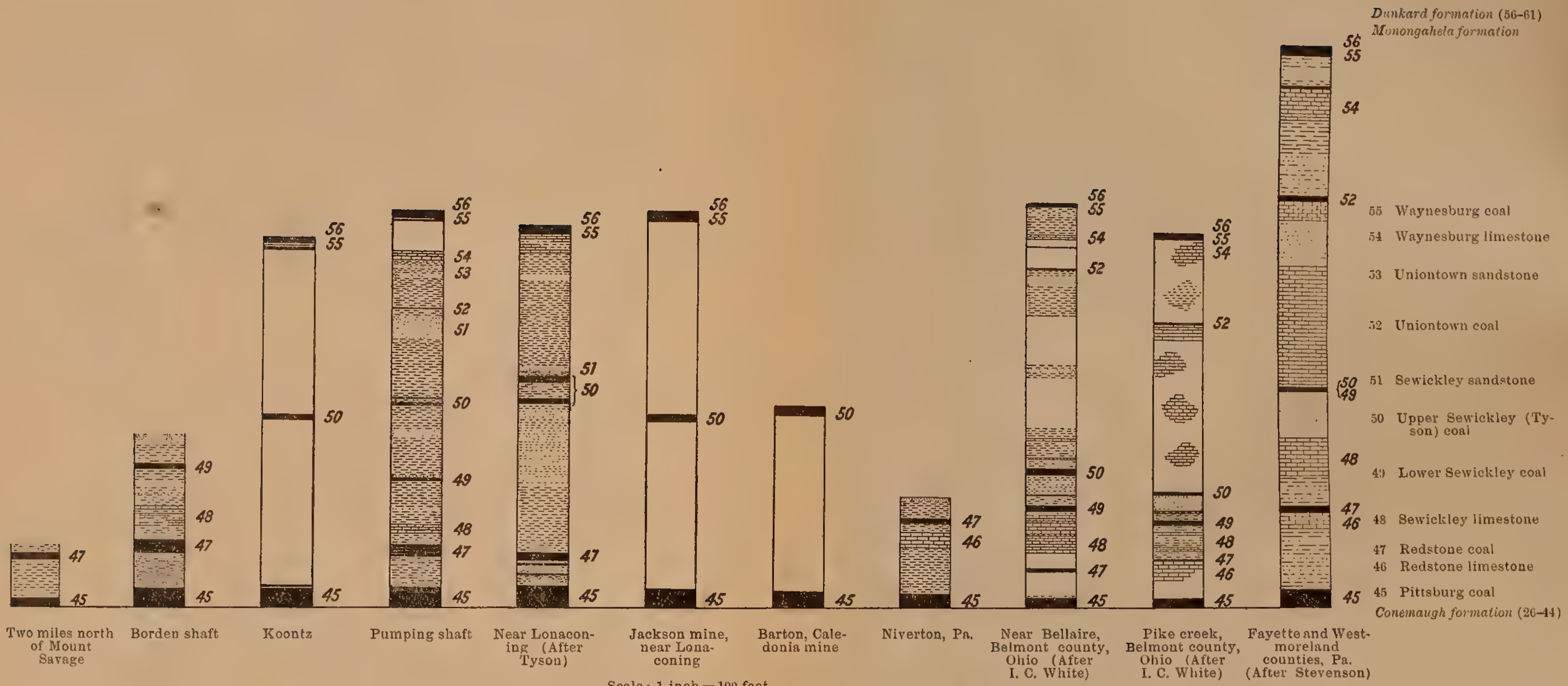
Near Bellaire, Belmont county, Ohio (After I. C. White)

Pike creek, Belmont county, Ohio (After I. C. White)

Fayette and Westmoreland counties, Pa. (After Stevenson)

55	Waynesburg coal
54	Waynesburg limestone
53	Uniontown sandstone
52	Uniontown coal
51	Sewickley sandstone
50	Upper Sewickley (Tyson) coal
49	Lower Sewickley coal
48	Sewickley limestone
47	Redstone coal
46	Redstone limestone
45	Pittsburg coal

Conemaugh formation (26–44)


Dunkard formation (56–61)
Monongahela formation
55 Waynesburg coal
54 Waynesburg limestone
53 Uniontown sandstone
52 Uniontown coal
51 Sewickley sandstone
50 Upper Sewickley (Tyson) coal
49 Lower Sewickley coal
48 Sewickley limestone
47 Redstone coal
46 Redstone limestone
45 Pittsburg coal
Conemaugh formation (26–44)
Two miles north of Mount Savage
Borden shaft
Koontz
Pumping shaft
Near Lonaconing (After Tyson)
Jackson mine, near Lonaconing
Barton, Caledonia mine
Niverton, Pa.
Near Bellaire, Belmont county, Ohio (After I. C. White)
Pike creek, Belmont county, Ohio (After I. C. White)
Fayette and Westmoreland counties, Pa. (After Stevenson)
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Scale: 1 inch = 100 feet

SECTIONS OF THE MONONGAHELA FORMATION

H. D. Roger in 1840* for the Upper Coal Measures as exposed in the valley of the Monongahela river. The name has had a varied usage since then, part of the time being employed in a broader sense to include the upper half of the Coal Measures. The U. S. Geological Survey in its Piedmont folio has employed the term Elkgarden formation for all of the beds above the base of the Pittsburg coal.

Pittsburg coal (45).—At the base of the Monongahela formation is the seam of coal known locally as the "Big vein" or "Fourteen-foot" coal This seam in its stratigraphic relations to the overlying and underlying beds corresponds exactly to the Pittsburg coal. The fauna of the roof shales, as far as our present knowledge goes, is the same. Dr I. C. White† has pointed out the identity of structure within the bed. The following sections showing the resemblance of the bed in the type locality to a typical Georges Creek section are quoted from Doctor White's paper:

Section of the Pittsburg Coal at Lonaconing

	Inches
"Roof" coal, with slate parting below	20
"Breast" coal, 6 inches of bone on top	91
Slate	1
"Bearing-in" coal	4½
Slate	0¾
"Brick" coal	16
Slate	0¼
"Bottom" coal	15

Section of the Pittsburg Coal at the Ormsby Mine, Pittsburg

			Inches
"Roof"	Coal	6	56
	Clay	2	
	Clay	8½	
	Parting	0½	
	Coal	2	
	Clay	9	
	Coal	8	
	Parting	0½	
	Coal	9	
	Clay	0½	
	Coal	5	
	Parting	0½	
	Coal	2	
	Parting	0½	
	Coal	2	

---

* Fourth Annual Report of the Geological Survey of the State of Pennsylvania, p. 150.

† The Pittsburg Coal Bed, Amer. Geol., vol. xxi, pp. 49-60.

	Inches
"Over"-clay	9
"Breast" coal	33
Parting	0¼
"Bearing-in" coal	4
Parting	0¼
"Brick" coal	10
Parting	0¼
"Bottom" coal	14

The various elements composing the seam are constant and characteristic in number and relative position. The relative thickness of these individual elements varies from place to place. From the Pittsburg region toward the southeast there is a gradual increase in the thickness of the "breast" coal, which reaches a maximum in the southern end of the Georges Creek basin, where the entire vein has been found at a single locality to reach 22 feet in thickness. There is greater change within the limits of the Georges Creek basin than there is between the central part of the Georges Creek basin and the Pittsburg region. This change consists chiefly in an increase in the number and thickness of the shales at the expense of the "breast" coal. This seam was called the Pomeroy coal in the Ohio reports and the Elkgarden coal in the Piedmont folio of the U. S. Geological Survey and in the Report on the Geology of Allegany County. The name Pittsburg coal was applied to this seam by J. P. Lesley in 1856.

Redstone limestone (46).—A thin limestone is sometimes found a few feet above the Pittsburg coal. In this region it is commonly separated from it by argillaceous shales. It occurs in the position of the Redstone limestone of Pennsylvania.

Redstone coal (47).—At an interval of from 18 to 45 feet above the Pittsburg coal is a seam of coal which corresponds in position to the Redstone coal of Pennsylvania. It is apparently very constant in the Georges Creek basin, although it has not been prospected for, and has accordingly not been opened at many points. The thickness is about 4 feet.

Sewickley limestone (48).—A bed of limestone occurs about 10 feet above the Redstone coal. It is in the stratigraphic position of the Sewickley limestone of Pennsylvania.

Lower Sewickley coal (49).—At an interval of from 25 to 30 feet above the Sewickley limestone, and from 40 to 45 feet above the Redstone coal, is a thin seam of coal which has been recorded only from Borden shaft and the Pumping shaft in the Georges Creek basin. This seam occurs at the horizon of the Sewickley coal. As there is another seam above this, however, which still falls within the limits of the Sewickley, and

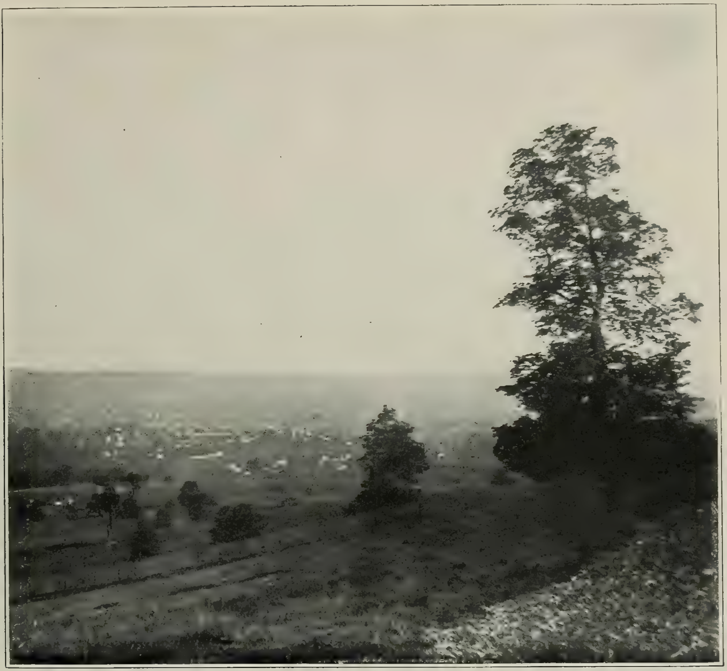

Figure 1.—Monongahela and Dunkard Topography near Frostburg

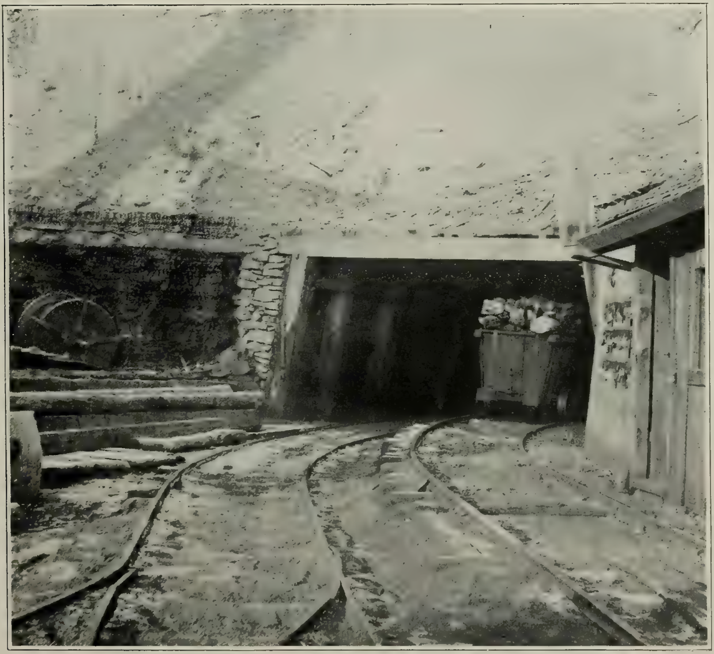

Figure 2.—Pittsburg Coal, near Lonaconing

MONONGAHELA AND DUNKARD FORMATIONS

as the Sewickley coal, in being traced westward from its type locality by the Pennsylvania geologists, has been found to split into two seams, it is considered probable that the same has taken place to the eastward. This seam is therefore referred to the Lower Sewickley.

Upper Sewickley or Tyson coal (50).—A seam of coal of great persistence and considerable economic importance is found at an interval of about 45 feet above the Lower Sewickley, and from 105 to 120 feet above the Pittsburg coal. This seam has long been known in the Georges Creek region as the Tyson or " Gas " coal. As is stated above, this seam falls within the position of the Sewickley coal, and probably corresponds to the upper split of the Sewickley in western Pennsylvania and eastern Ohio.

Sewickley sandstone (51).—Separated from the underlying Upper Sewickley coal by a variable thickness of shale is a sandstone whose greatest observed thickness in Maryland is about 15 feet. Dr I. C. White, in Bulletin No. 65 of the United States Geological Survey, calls attention to the fact that either a limestone or a sandstone, one only, however, to the exclusion of the other, occurs in the interval between the Sewickley and the Uniontown coals. Where sandstone occurs in this interval it is called the Sewickley sandstone. The limestone, on the other hand, has been differentiated into the Uniontown and "Great" limestones. Throughout Maryland the limestone is apparently entirely absent. This occurrence therefore confirms the generalization which Doctor White based on his observations in Pennsylvania, West Virginia, and Ohio, namely, that either the limestone or the sandstone, but never both, are found in the interval between the Sewickley and Uniontown coals.

Uniontown coal (52).—A thin coal is found in the pumping shaft section near Frostburg, about 60 feet above the Upper Sewickley coal and close to the top of the Sewickley sandstone. It corresponds in position and character to the Uniontown coal of Pennsylvania.

Uniontown sandstone (53).—A short distance above the Uniontown coal, in the Pumping Shaft section, there is a thin sandstone which is probably a poor representation of the Uniontown sandstone.

Waynesburg limestone (54).—A limestone occurs a short distance above the Uniontown sandstone and from 20 to 30 feet below the top of the formation which corresponds in its stratigraphic position to the Waynesburg limestone of Pennsylvania and West Virginia.

Waynesburg coal (55).—There is a very persistent coal seam, of considerable economic importance, that may occur anywhere in the interval up to 20 feet above the top of the Waynesburg limestone. From its position, 230 to 250 feet above the base of the Monongahela formation, and in its regular stratigraphic sequence, it is regarded as the Waynesburg coal. In the Report on the Geology of Allegany County it was named the Koontz coal, from its occurrence at the mining village of that name near Lonaconing. The identity of this seam with the Waynesburg seams now appears so certain that the name Koontz will be considered as a synonym. The upper part of this coal is the top of the Monongahela formation.

DUNKARD FORMATION

Composition and relations.—The strata here referred to the Dunkard formation have an extreme thickness of 390 feet in Maryland. It is evident that the entire formation is not represented. The present area of the Dunkard deposits in Maryland is restricted to a few small tracts in the central part of the Georges Creek basin. The surface has so little relief that there are few good exposures, and it is almost impossible to obtain a detailed section. In consequence the stratigraphic sequence is very imperfectly known.

The Dunkard formation was named by Dr I. C. White in 1891 * from Dunkard creek, in southwestern Pennsylvania. The rocks of this formation had before been known as the "Upper Barren Coal Measures" or "Upper Barren Measures," and they were divided into the "Green County group" and the "Washington County group." As will be noted below, the strata in Maryland belong almost exclusively to the latter division.

Waynesburg sandstone (56).—A sandstone of no very great prominence occurs a short distance above the Waynesburg coal. It probably represents the Waynesburg sandstone, since its stratigraphic position is the same.

Waynesburg "A" coal (57).—A thin coal which corresponds in position to the Waynesburg "A" coal of Pennsylvania and West Virginia is found on top of the Waynesburg sandstone, and about 45 feet above the Waynesburg coal.

Washington coal (58).—About 75 feet above the Waynesburg "A" coal, and separated from it by an interval consisting in Maryland apparently of shales and limestones, is a seam of coal whose character is not well known. The thickness of this coal is 4 feet or less, but its quality is not known. This coal corresponds in position to the Washington coal of Pennsylvania.

Upper Washington limestone (59).—A bed of limestone approximately 4 feet in thickness occurs about 170 feet above the Washington coal, and

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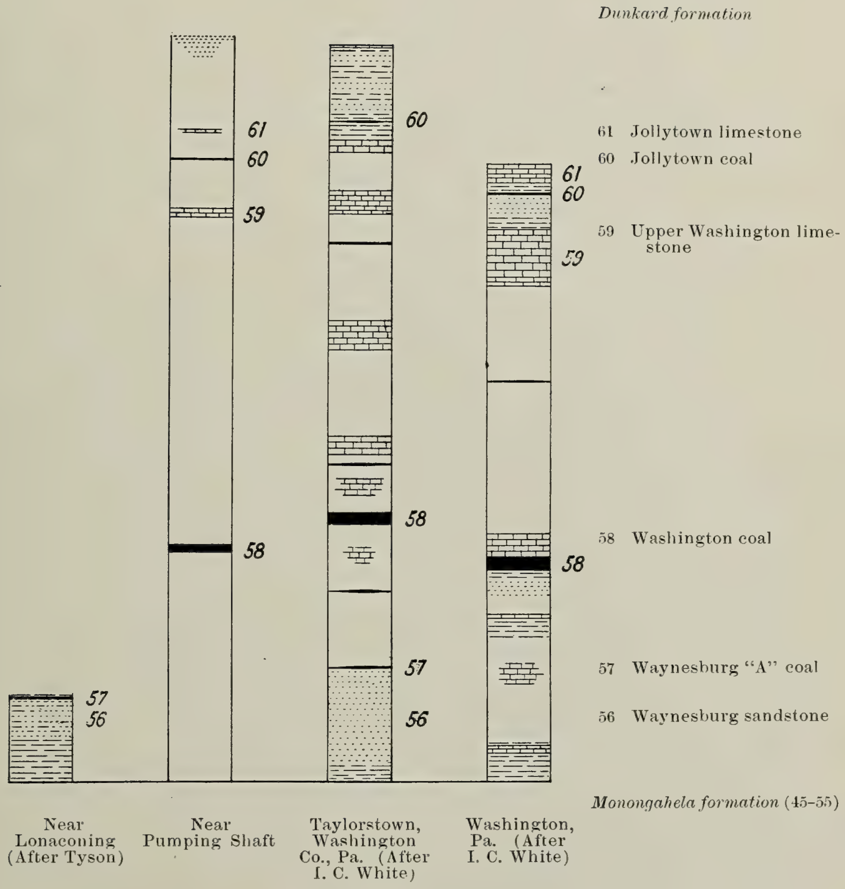
* Stratigraphy of the Bituminous Coal Fields of Pennsylvania, Ohio, and West Virginia. Bull. No. 65, U. S. Geological Survey, p. 20.


Dunkard formation
61 Jollytown limestone
60 Jollytown coal
59 Upper Washington limestone
58 Washington coal
57 Waynesburg "A" coal
56 Waynesburg sandstone
Monongahela formation (45-55)
57
56
61
60
59
58
60
58
57
56
61
60
59
58
Near Lonaconing (After Tyson)
Near Pumping Shaft
Taylorstown, Washington Co., Pa. (After I. C. White)
Washington, Pa. (After I. C. White)

Scale: 1 inch = 100 feet

COLUMNAR SECTIONS OF THE DUNKARD FORMATION

is separated from it by an interval of unknown rocks, apparently shale with some limestone. It is in about the position of the Upper Washington limestone of Pennsylvania.

This stratum is important, inasmuch as its top is the dividing plane between the two divisions of the Upper Barren Measures or Dunkard formation. Almost all of the Dunkard in Maryland falls in the lower division or Washington County group of Stevenson, while the upper or Green County group of Rogers is represented in Maryland by only the 65 to 90 feet of strata overlying this, and which cover an area of only a few acres.

Jollytown coal (60).—A thin seam of coal is found about 25 feet above the outcrop of the Upper Washington limestone. It is apparently in the stratigraphic position of the Jollytown coal of Green county, Pennsylvania.

Jollytown limestone (61).—A limestone of apparently no very great thickness is found about 15 feet above the Jollytown coal. It is in the position of the Jollytown limestone of Pennsylvania.

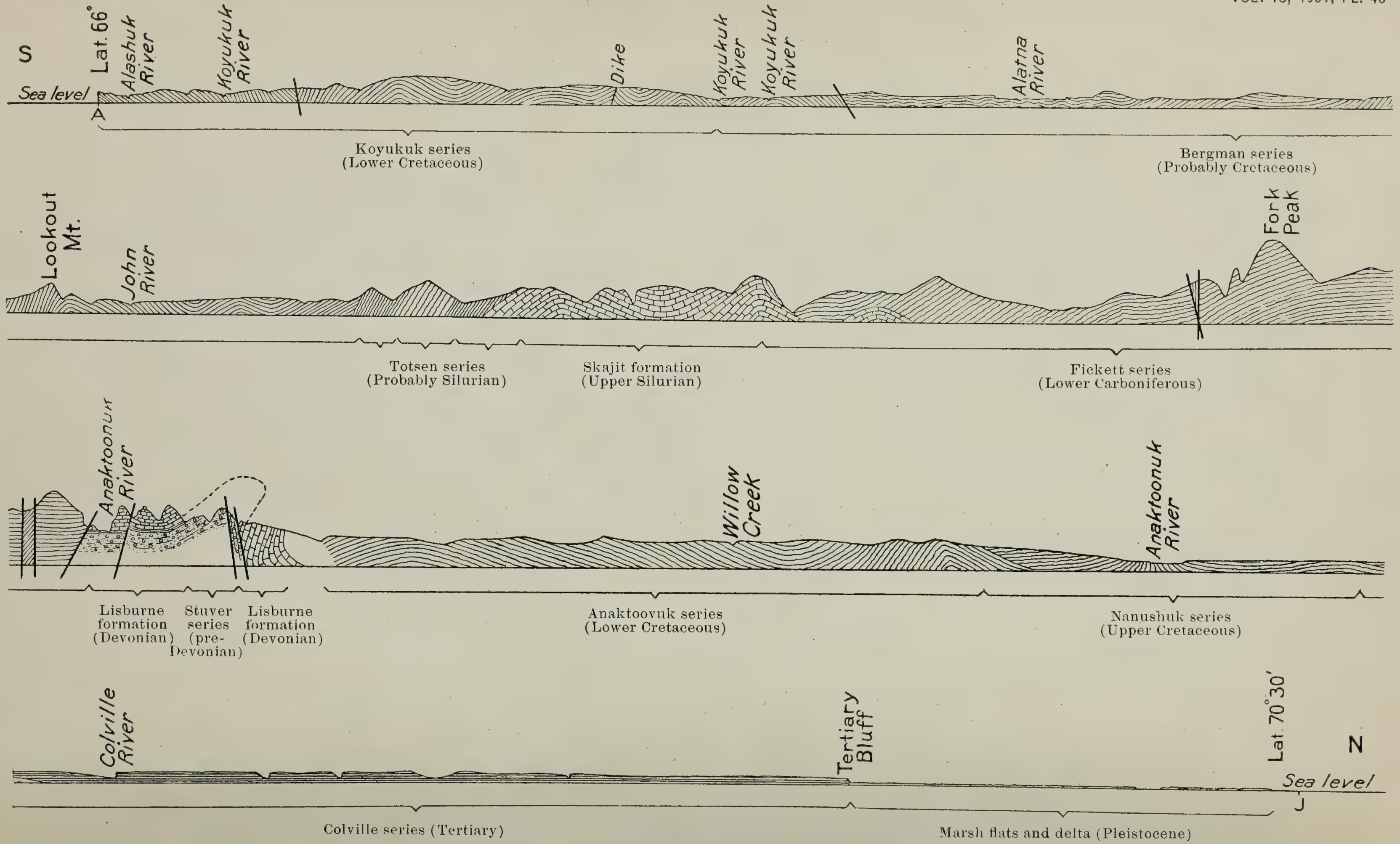
Above this limestone there are no good exposures, and not more than 50 feet of strata are preserved in Maryland. The highest bed is a sandstone which caps the hill east of Borden shaft.

CONCLUSIONS

The detailed comparisons given in the preceding pages show that the various members of the Coal Measures of Maryland closely resemble those found in Pennsylvania and West Virginia. They clearly demonstrate the fact, if any such demonstration is necessary, that the various beds of the Coal Measures have a wide geographical extent, and that the individual coal beds possess certain marked physical characteristics that can be readily distinguished over wide areas. The similarity of sequence of the various members of the coal series is so striking and the faunal and floral characteristics so marked that the determination of the horizons of the several coal seams can be made with remarkable accuracy. In the lower formations of the Coal Measures it has been possible to establish this identity with the Pennsylvania and West Virginia deposits on the basis of actual continuity of the beds, although this is not possible in the higher members of the series. The sequence of deposits and faunal and floral characteristics are such, however, that very little doubt can exist regarding their equivalency.

The following table shows the sequence of Carboniferous and Permian (?) formations in the northern Appalachians as developed in Maryland and adjacent states:

Group	*Formation*	*Age*
Coal Measures	Dunkard	Permian (?)
	Monongahela	Carboniferous
	Conemaugh	
	Allegheny	
	Pottsville	
	Mauch Chunk	
	Greenbrier	
	Pocono	


S
Lat. 66°
Sea level
A
Alashuk River
Koyukuk River
Dike
Koyukuk River
Koyukuk River
Alatna River
Koyukuk series (Lower Cretaceous)
Bergman series (Probably Cretaceous)
Lookout Mt.
John River
Fork Peak
Totsen series (Probably Silurian)
Skajit formation (Upper Silurian)
Fickett series (Lower Carboniferous)
Anaktoonuk River
Willow Creek
Anaktoonuk River
Lisburne formation (Devonian)
Stuver series (pre-Devonian)
Lisburne formation (Devonian)
Anaktoovuk series (Lower Cretaceous)
Nanushuk series (Upper Cretaceous)
Colville River
Tertiary Bluff
Lat. 70° 30′
N
Sea level
J
Colville series (Tertiary)
Marsh flats and delta (Pleistocene)

GEOLOGICAL RECONNAISSANCE SECTION OF THE ROCKY MOUNTAINS IN NORTHERN ALASKA FROM KOYUKUK RIVER (LAT. 66°) TO THE ARCTIC COAST (LAT. 70° 30′)

Vertical exaggeration about 5 : 1.

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 13, PP. 233-252, PLS. 40-43 JULY 29, 1902

GEOLOGICAL SECTION OF THE ROCKY MOUNTAINS IN NORTHERN ALASKA*

BY F. C. SCHRADER

(Presented before the Society January 2, 1902)

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    Age 244

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* Published by permission of the Director of the U. S. Geological Survey.

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Geography and Topography

IN GENERAL

The section lies in the hitherto unexplored part of northern Alaska. It extends from the 66th parallel north latitude roughly along the 152d meridian by way of the Koyukuk, John, Anaktoovuk, and Colville rivers, a distance of nearly 400 miles, to the Arctic coast.*

Geographically the region traversed by the section comprises three distinct provinces, that of the Koyukuk or southern, the mountain or middle, and the Arctic slope or northern.

KOYUKUK PROVINCE

This province, extending from the 66th parallel more than 100 miles northeastward to the southern base of the mountains, lies mainly in the northwestern part of the large Koyukuk basin.† The province in gen-

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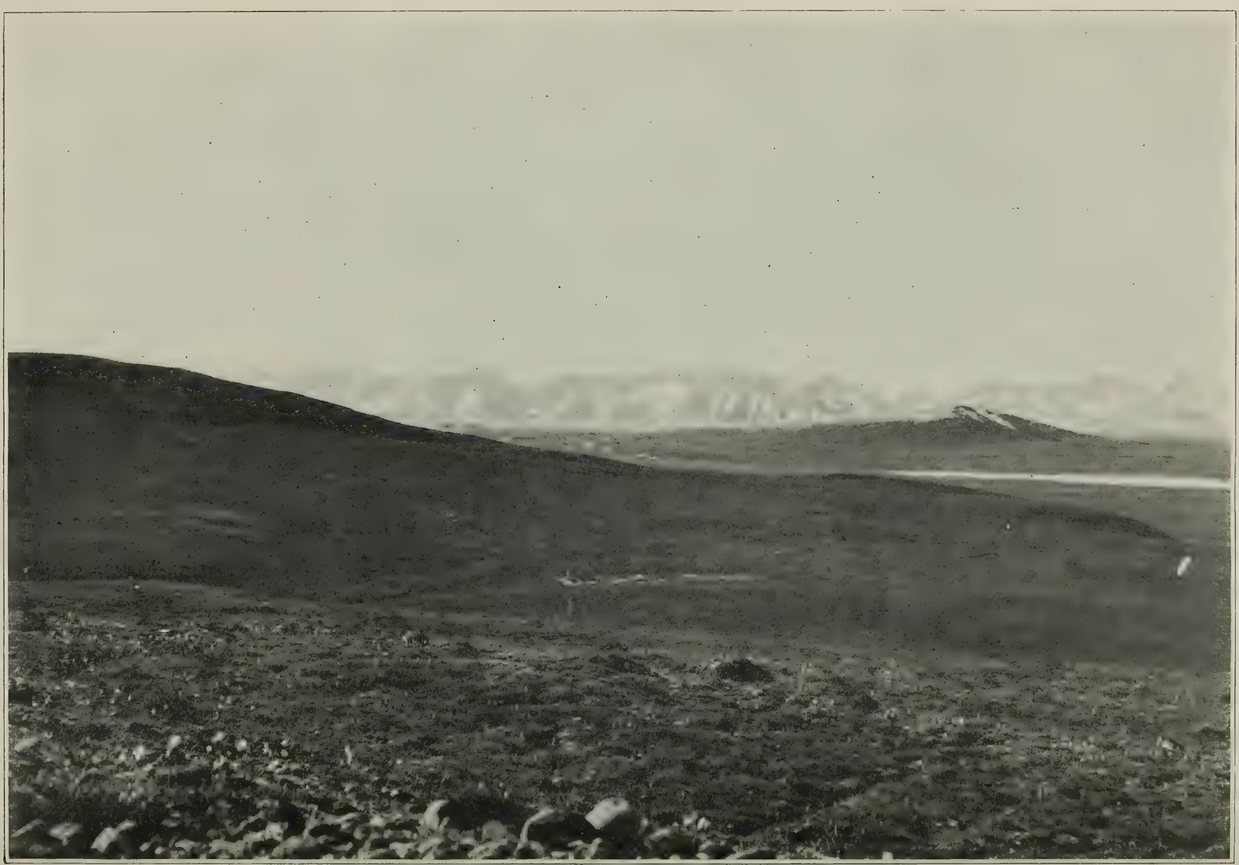
* For a fuller account of this region the reader is referred to the Preliminary Report on a Reconnaissance in Northern Alaska along the 152d Meridian to the Arctic Coast, soon to be published by the U. S. Geological Survey.

† For a more complete description of the Koyukuk basin the reader is referred to "Preliminary report on a reconnaissance along the Chandlar and Koyukuk rivers, in Alaska, in 1899." Twenty-first Ann. Rep. U. S. Geol. Survey, part 2, p. 467. See also "Bulletin of the American Geographical Society," vol. 34, No. 1, February, 1902: "Recent work of the U. S. Geological Survey in Alaska," p. 1.



EDGE OF ANAKTOOVUK PLATEAU AND BASE OF ENDICOTT RANGE eral consists of a rolling country composed essentially of Mesozoic rocks whose low, rounded hills and ridges vary from 1,000 to 3,000 feet in elevation. It is supposed to represent the Koyukuk portion of the Yukon plateau, but which here is not distinctly marked. The drainage, which is separated from that of the Arctic slope by the Endicott mountains, is southwestward. The master stream is the Koyukuk, which flows into the Yukon, while the large tributaries are South Fork, John, Alatna, and Alashuk rivers. The lower part of all these tributaries, as well as the Koyukuk, meanders in wide valley flats, bordered by the rolling country which has been noted. The Koyukuk river is navigable by steamboats to Bettles, near the 67th parallel, a distance of about 530 miles above its confluence with the Yukon.

MOUNTAIN PROVINCE

The middle or mountain province is the most striking. It consists of a rugged range of mountains composed of Paleozoic rocks extending east and west across the field between latitudes 67° 10′ and 68° 25′. These mountains, for which the name Endicott is locally proposed, here have a minimum width of 80 miles and an average elevation of 6,000 feet. Orographically the range is regarded as the northwestward continuation of the Rocky Mountain system of the United States and British Columbia, which here trends nearly east and west entirely across northern Alaska, forming the great Transalaskan watershed between the Yukon on the south and the drainages of the Arctic ocean on the north.

In their northward and finally westward course they form a prominent feature of the concentric geography of Alaska, and embrace in the concavity which they present on the south the great basin of the Yukon and its well known but not always distinct feature, the Yukon plateau. West of the 153d meridian, in the region of the head of the Colville and the Noatak rivers, the mountains decrease in elevation and seem to divide or fork, forming two ranges. The northern range, continuing westward, terminates in the low mountains and abrupt sea cliffs of cape Lisburne at Bering sea, while the southern forms the divide between the Noatak and the Kobuk rivers.

On the southern side the rise from the rolling Koyukuk country is by means of foothills, but rapid. On the north the mountains break off somewhat abruptly, much as they do along the edge of the Great plains in the western United States, as shown in plate 41. Pronounced faulting and uplift are evidenced by marked deformation of the strata and the presence of fault scarps, sometimes recognizable for miles. Where they were crossed the mountains locally present a crescentic or concave front to the northward, which is followed by low concentric ridges in the plateau beyond, though these grow weaker and die out farther northward.

Where best observed during the past season, principally on the John and Anaktoovuk rivers, a view across the top of the range presents the general appearance of a deeply dissected plateau or baselevel plain, which has probably been uplifted from near sealevel, and whose former surface is denoted by the expanse of closely crowded peaks, which in general rise to an elevation of 6,000 feet, forming an even sky line, as shown in plate 42. The floors of the mountain valleys lie at about 2,000 feet, and the open pass near the northern edge of the range between the John and the Anaktoovuk rivers lies at an elevation of scarcely 2,500 feet. For this dissected plateau feature at the top of the range the name Endicott plateau is proposed.

It seems not improbable that, as our knowledge of the physical geography of Alaska becomes more complete, it may be found that the Endicott plateau, having probably a considerable extension to the eastward, may be correlated with similar features, namely, the Chugatch plateau, representing the westward continuation of the Saint Elias range in southern Alaska, whose dissected surface also lies at an elevation of about 6,000 feet.*

The drainage of this portion of the range is principally southward into the Koyukuk. The master stream is the John river, rising near the northern edge of the range. The main drainage ways are therefore of a transverse character, extending across the strike and trend of the rocks as well as across the trend of the range, while the tributaries of these larger streams, being nearly always controlled by structure, flow in general along the strike to enter the master streams, producing a rectangular system of drainage. John River valley may be characterized in general as open, though certain sections are canyonous, because of the character and structure of the rocks. Benching or remnants of old valley floors occur at heights respectively of 1,700, 600, and 100 feet above the present stream, and seem to mark stages of comparative rest in the progress of orographic uplift of the land mass from a former lower level. Northward sloping benches at the head of John river denote that a large area of the drainage at the head of this stream, now flowing southward into the Koyukuk, formerly drained northward and entered the Arctic ocean through the Anaktoovuk and the Colville instead of Bering sea through the Koyukuk and the Yukon, as at present.

COLVILLE OR ARCTIC SLOPE PROVINCE

This northern geographic province extends from the northern base of the mountains, in latitude 68° 25′, northward to the Arctic coast, a dis-

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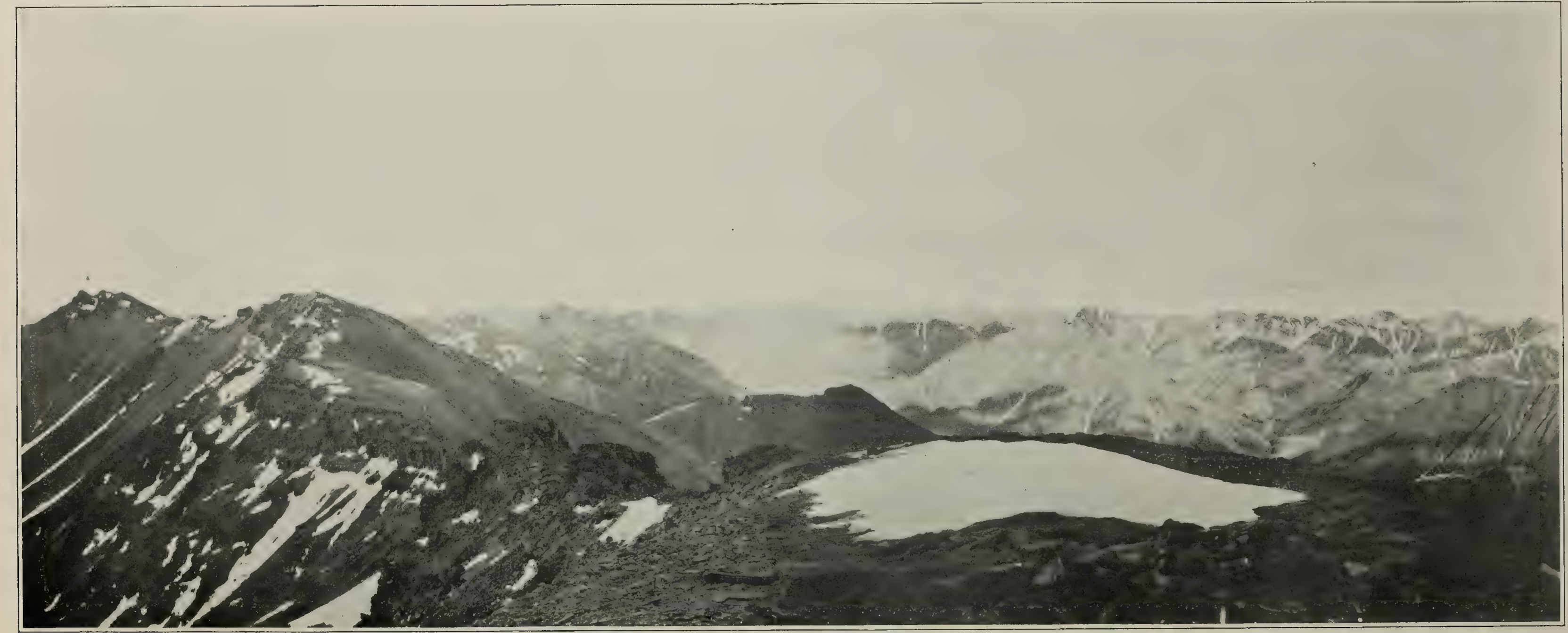
*The geology and mineral resources of a portion of the Copper River district, Alaska. U. S. Geological Survey, Washington, 1901.



ENDICOTT PLATEAU AND ENDICOTT MOUNTAINS CARVED FROM IT

tance of 160 miles. It consists primarily of two distinct features, a very gently rolling plains country, for which is proposed the name Anaktoovuk plateau, and a nearly flat tundra country or coastal plain. The inland edge of the Anaktoovuk plateau, which is composed of Cretaceous rocks, has an elevation of 2,500 feet, and with gentle slope extends northward for a distance of 80 miles to latitude 69° 25′, where, at an elevation of 800 feet, it is succeded by the nearly flat Tertiary coastal plain, which, with very gentle slope, extends 80 miles farther northward to the Arctic coast. The drainage of this province is almost directly northward into the Arctic ocean. The master stream is the Colville, whose headwaters, so far as known, seem to make a somewhat wide detour to the westward before flowing directly to the sea. The next larger stream is the Anaktoovuk, which, rising in the mountains just east of the head of John river, flows northward through the southern part of the province and into the Colville. The most prominent features of the plateau are a few low, transverse ridges, extending across it from east to west, feebly imitating the front of the mountain range and the shallow valleys that carry off the drainage.

The coastal plain, which is underlain by Tertiary beds, has a breadth of about 80 miles. It descends with very gentle slope from an elevation of 800 feet in the interior to near sealevel at the coast. In its inland portion, the Colville river has sunk its bed to a depth of 200 feet below the surface of the plain, but the interstream areas are flat, with the surface, which appears to be fresh-constructional in form, dotted here and there by extremely shallow ponds and lakelets, which in most instances are without outlet and present no suggestion of progress toward the development of any system of drainage.

Geological Section

The horizontal scale of the section (plate 40) is 10 miles per inch. In order to show the structure in the Tertiary coastal plain and represent the flats and delta near sealevel at the north, it has been given a vertical exaggeration of 5:1. As the section is confined to the line of traverse, in order to represent more accurately the relations of the rocks as actually observed, it deviates somewhat from a straight line in its extent across the field from A to J. Owing to this restriction to the line of traverse in the valleys where the relief has been relatively reduced by erosion, especially in the mountainous portions, the profile rarely rises to the normal height of the top of the Endicott plateau; consequently this plateau feature of the range is not represented by the profile of the section. At the northern base of the mountains, where the profile descending from the mountains, passes from the upturned Devonian on to Pliestocene till, which is soon found resting on Lower Cretaceous, a belt of several miles has been left blank. It is thought possible that Carboniferous and Lower Mesozoic strata may occur in this region between the Devonian and the Lower Cretaceous.

The rocks encountered comprise representatives of most of the geologic formations from Silurian to Recent. In point of distribution, as shown in the section, they consist primarily of a belt of Paleozoics 80 to 100 or more miles in width, constituting the Endicott mountains, against whose slopes, unconformably on either side, rest the edges of the plateaus or uplands, composed of Mesozoics, which in turn are succeeded by Tertiary. Beginning with the oldest, these several formations or rock series will be briefly noted. As the field is new, the names here employed to designate the various formations or series are proposed provisionally. To afford a more comprehensive view of the relations of the several series and avoid repetition in referring to them individually, it may be well to note at the outset some features of structure which are common to nearly all the Paleozoic series and apply to the range as a whole, namely, that the series all strike or trend approximately east and west, parallel with the trend of the range. They are nearly all traversed by the dominant jointing or major structure of the range, cutting the rocks in a northeast and southwest direction, with dip nearly vertical or steeply northwest, at an angle of 75 to 80 degrees. This dip may be considered normal, since the uplift of the land mass of the range to the east exceeds that on the west. The series also nearly always exhibit one or more sets of secondary jointing or minor structure, trending in a general northwest or southeast direction, approximately at right angles to the major structure. The above statements of structure pertaining to the Paleozoics in the range apply also in a limited way to the adjacent Mesozoics on either side.

We may also note that, with the exception of the greenstone schists occurring in the Totsen series, the Paleozoics of the range, as well as the younger formations of the Arctic slope, are all sedimentary and, so far as observed, free from igneous intrusions of any kind.

The Endicott range consists of two somewhat distinct geologic axes, of which the southern seems to be composed of the oldest rocks, namely, the Skajit formation, and the Totsen series, of which the former is the most prominent.

PALEOZOICS

SKAJIT FORMATION (UPPER SILURIAN)

Character and occurrence.—The rocks of the Skajit formation consist of heavy-bedded limestone and mica-schist. The limestone is highly altered, being finely crystalline, schistose, and often micaceous. Some layers, becoming more and more foliated, grade into mica-schist. The series occurs in the southern part of the Endicott mountains, where its breadth or exposure in a north and south direction is 15 or 20 miles. Here it rises to a height of more than 5,500 feet, forms some of the highest and most rugged topography of the southern axis, and seems to have a thickness of at least 4,000 feet.

Structure.—So far as known, the formation has a general east and west strike, parallel with the trend of the mountains. The middle portion is synclinal, while the northern and southern edges are anticlinal. The formation is unconformable with the Fickett series of the north and apparently so with the Totsen series on the south, both of which it seems to underlie. In general the dips are gentle, but in some localities faulting and folding has been intense. The rocks are cut by the major and minor jointings of the range, with the joint planes sometimes locally followed by veins of calcite and quartz, containing occasionally a little galena or pyrites of iron and copper.

Age.—Though the limestone, as noted, is much altered by metamorphism, it contains imperfect faunal remains, one of which has been identified by Mr Charles Schuchert as probably Meristina or Meristella, referring the formation provisionally to upper Silurian and placing it among the oldest known fossil-bearing rocks of northern Alaska and the northern part of North America.

TOTSEN SERIES (SILURIAN)

Character and occurrence.—This series of rocks, including a strip of greenstone schist, occupies an east and west belt 12 miles in width. It occurs to the south of the Skajit formation, which it seems to unconformably overlie, while it unconformably underlies the Bergman series on the south. The rocks consist mainly of mica-schist and some quartz mica-schist, in both of which the essential minerals are biotite and quartz. Locally the rock becomes graphitic and in cases carries considerable quartz in small veins and lenticular bodies, some of which may be the source of the placer gold colors found in the gravels. The series is essentially of sedimentary origin, but the period of sedimentation seems to have been accompanied by igneous effusives or flows of basaltic character, which were later sheared and schisted with the sedimentary beds, giving rise to greenstone schist, of which the most prominent belt, having a width of several miles, occurs in the southern part of the field. Though on account of deformation and folding there is probably some duplication in the Totsen series, its total thickness, by conservative estimate, is probably 6,000 or 7,000 feet.

Structure.—The Totsen series, like the other rocks composing the range, trends approximately east and west, and though as a whole the series has been intensely folded, the dip in general is monoclinal, being southward at an angle of 60 degrees. The major and minor jointings of the range are pronounced. Cleavage was noted at several localities.

Age.—Though the Skajit formation and the Totsen series have undoubtedly been folded and crushed together, judging from the apparent higher degree of metamorphism in the Totsen series we should infer that it may prove to be the older, notwithstanding, it seems to overlie the southern edge of the Skajit formation. It is provisionally referred to the Upper Silurian with the Skajit series.

STUVER SERIES (PRE-DEVONIAN)

Character and occurrence.—The Stuver series is the oldest group of rocks exposed in the northern axis of the Endicott range, of which they form the core. This is on the east and west line of the most pronounced and geologically most recent crustal disturbance. The uplift, which seems to have been going on since middle or late Paleozoic time, has taken the form of a broad anticline whose longer limb extends to the southward, while the shorter forms in part the north front of the range. Elevation was accompanied by faulting; the movement or thrust came from the south, and along the axis of the anticline has produced an over thrust fold or fan structure. On the north, faulting has resulted in the breaking of the strata and the formation of a fault scarp in the north limb of the anticline, between the north edge of the Stuver series and the Lisburne formation. This was farther accompanied and followed by faulting and erosion, which broke up the immediate region into several great fault blocks, and finally brought the Stuver series into view along the bight of the fold. From the north edge of the range pronounced faulting extends southward into the range for a distance of 15 or 20 miles. The Stuver series consists primarily of hard flinty conglomerate and quartzite, with some slate and shale.

Structure.—The exposure is limited to a narrow belt about 5 miles in width, trending northward for an unknown distance from the Anaktoovuk valley between the faulted and eroded edges of the Lisburne formation on either side. On the south, by uplift and faulting, it has probably been brought into contact with the lower Carboniferous of the Fickett series. Both here and at the north edge of the series, the faulting, as shown in the section, seems to be normal, but in the Stuver series the major jointing trends about east and west and the minor nearly north and south. The series is cut by a well marked cleavage, dipping northwest at an angle of 45 degrees. The undisturbed relation of the Stuver series to the Lisburne formation is apparently conformable. If any unconformity exists, it must be very slight.

No estimate can be formed of the thickness of the Stuver series, as its lower limits are unknown. The exposed portion amounts to approximately 2,000 feet.

Age.—From its position below the the Lisburne series, which is considered to extend to below the middle Devonian, the Stuver series can certainly not be younger than lower Devonian, and is regarded probably pre-Devonian, to which it is provisionally referred.

LISBURNE FORMATION (DEVONIAN)

Character and occurrence.—The Lisburne formation consists of medium-bedded limestones, with some shale. It occurs next above the Stuver series, and. like the latter, has been greatly disturbed by crustal movements. It forms a belt 15 or more miles in width, extending east and west across the valley of the Anaktoovuk. On the southwest it is soon delimited by the fault scarp of Contact creek, and farther westward by the Carboniferous of the Fickett series, with which its relations are not definitely known. To the eastward of the Anaktoovuk the belt seems to widen. The series is probably in contact with the Carboniferous on the south, while in descending the slope of the mountains on the north it disappears beneath the mantle of glacial till, where, judging from topography, it is probably soon met and overlain by the Mesozoic or Lower Cretaceous. From what has been observed in the region of the Anaktoovuk, the thickness of the formation is probably a little over 3,000 feet.

Structure.—The entire area of the Lisburne formation here considered is more or less deeply involved in the system of faulted and disturbed blocks referred to under the Stuver series. At the north base of the mountains west of the Anaktoovuk, the formation disappears beneath the covering of glacial drift with a dip of 60 degrees to the north, while east of the Anaktoovuk, a couple of miles distant, it similarly disappears, but with a dip to the south at an angle of 75 degrees against the fault scarp of the Stuver series, as shown in the section, plate 40.

Age.—On the basis of Devonian fossils found in surface fragments near the top of the mountains formed by the Lisburne formation, the latter is provisionally referred to the Devonian.

The Upper Devonian fossils thus collected by the writer have been identified by Mr Schuchert as follows:

Zaphrentis.
Aulocophyllum.
Diphyphyllum.
Fenestella.
Unitrypa
Hemitrypa.
Rhombopora.
Eridotrypa near or identical with *E. barrandei* (Nicholson).
Productella two species.
Spirifer disjunctus.
Platyostoma.

Fossils were also found in place, but these are too highly altered and crushed for identification.

FICKETT SERIES (LOWER CARBONIFEROUS)

Character and occurrence.—The Fickett series comprises rocks of very diverse character, ranging from chloritic schists or phyllites on the south, through limestone, slate and sandstone, quartzite, and grit, to hard conglomerate on the north. As shown in the section, figure 1, the series, roughly speaking, lies essentially in the broad trough between the two axes of the range already described. This trough was probably occupied by a shallow arm of the sea in late Paleozoic time, when the axis on the north and the south stood above sealevel, and from which sediments of the Fickett series have probably been in part derived. The series has a width or north and south extent of about 50 miles. On the south its edges rest unconformably on the Skajit formation of the southern axis, as shown in the geological section, while on the north, owing to the faulting, as noted at the head of the John and Anaktoovuk rivers, its relations to the older rocks of the northern axis are not definitely revealed. It seems, however, to meet the Stuver series and Lisburne formation by fault contact, as has been indicated in the section. To the north of this contact, so far as observed in the region of the Anaktoovuk, all trace of this series in place, though it must have been of considerable thickness, seems to have been removed by deformation and erosion. To the westward, however, beyond the limits of the fault-block system of the Devonian, at about 20 miles from the Anaktoovuk, the Fickett series, as already noted, seems to overlie the Lisburne formation and possibly extends beneath the Mesozoic at the north base of the range.

Structure.—The Fickett series, like the other Paleozoics of the range, has been subjected to faulting and folding incident to the mountain-building forces. The folding in some localities has been intense, as is shown by closely appressed anticlinal folds, and puckering in the schist. The structure, however, broadly speaking, is essentially monoclinal, with strike and trend east and west and the dip south at an angle of about 45 degrees, pointing strongly to a later and also to a greater elevation along the northern axis than along the southern. The major structure of the range is exhibited throughout the region covered by the Fickett series. There are many faults whose planes are usually slickensided and dip 70 to 80 degrees northwest. The minor jointing is also present. The schists, and notably the phyllites, often exhibit excellent cleavage, with medium north to northwest dips.

Age.—On the basis of Lower Carboniferous fossils found in the stream gravels, and the lithologic resemblance of the fossil-bearing gravels to the rocks contained in the series, and the relation of the series to the limestone formation, which seems to be Devonian and to underlie it, the Fickett series is provisionally assigned to Lower Carboniferous; but as the fossils are believed to occur near the base of the series, it probably contains also rocks younger than the Lower Carboniferous.

The following are the principal forms collected by the writer and identified by Mr Schuchert:

Lithostrotion.
Cystodictya nearest to *C. lineata.*
Streblotrypa near *nicklesi* Vine.
Rhombopora.
Fenestella.
Fenestella near *F. cestricensis* Ulrich
Pinnatopora.
Productus scabriculus Martin.
Productus semireticulatus Martin.
Spirifer striatus Martin.
Spirifer near *S. neglectus* Hall.
Spiriferina cristata Schlotheim

Mr Schuchert states that—

> "The above localities represent one formation, in the upper portion of the Lower Carboniferous. This fauna, however, is unlike that of the Mississippi valley, in that it does not have such characterizing fossils as the screw-like bryozoan Archimedes and the blastoid genus Pentremites.
>
> "The only other Alaskan region with which this Arctic Lower Carboniferous fauna can be compared is that found on Kuiu island, in southeastern Alaska."

CORRELATION OF PALEOZOIC

As lack of space forbids the correlation of each individual formation or series, especially of those of the Paleozoics, with similar formations of the same age in other parts of Alaska or the Arctic regions, it may here be briefly stated that the present season's work, together with the evidence previously collected to the eastward and that to the westward in the Cape Lisburne region, seems to indicate beyond question the extension of a well developed belt of Paleozoic formations across northern Alaska, along the Rocky mountains, from the 35th meridian near the Mackenzie to the 66th meridian at cape Lisburne, a distance of nearly 1,000 miles. In the Cape Lisburne region, as noted, these rocks, having a known width of 75 or more miles, terminate in abrupt sea cliffs. The thickness of the section here is not known, but it must be considerable, from which it seems safe to infer that as a submarine geologic axis the Paleozoics probably extend far seaward, and, as this part of the ocean is known in the main to be shallow, it is not unlikely that the same Paleozoic axis may continue across and reappear to the westward on the Siberian coast. It may be noted, however, that on the portions of this foreign coast visited by Doctor Dall he reports the rock to be essentially crystalline or igneous.

Mesozoics

CORWIN SERIES (JURA-CRETACEOUS)[*]

Character and occurrence.—The Corwin series is not represented in the section, nor is it known to extend so far eastward as the Anaktoovuk. It was encountered several hundred miles northwest of this on the coast near Wainright inlet, whence it extends southwestward a distance of 180 miles to near cape Lisburne, where it plays a very important part in the geological section of that locality, and since the topography and the open, uniform character of the intervening country suggests a probable great extension of the series to the eastward, and its geological horizon is known on fossil evidence to be above the Fickett and below the Anaktoovuk, to be next described, it seems not unlikely that the Corwin series occupying this horizon may extend far inland along the north slope of the range to near, if not beyond, the meridian of the section. The series consists of medium to heavy bedded impure gray and brown sandstone and arkose, with shale, shaly slate, and coal. The coal includes the Wainright, Beaufort, Thetis, and Corwin coals, to which the names Cape Lisburne coals and Cape Beaufort Coal Measures have also been collectively applied, and which are likely to prove of economic value. While the northwestern edge of the series forms the coast line, the southern edge seems to rest unconformably on the Paleozoics on the south.

Structure.—The beds lie nearly horizontal or dip southwest at an angle of 30 to 40 degrees, are slightly folded and faulted, and are traversed by two sets of jointings, one approximately parallel with the strike and the other approximately at right angles to it, agreeing in a general way with the major and minor structures in the inland portion of the range, as has been noted.

Age.—Fossil plants found in the Cape Beaufort region, and more particularly in the shale near the Thetis mine, at cape Sabine, by Mr Dumars and Mr Woolfe and others, have been identified by Professor Fontaine and Doctor Ward as not older than the Oolitic nor younger than the Lower Cretaceous, but as probably on a line between the two.[†]

On this evidence, together with forms collected by the writer from near Wainright inlet, the Beaufort series is provisionally assigned to the Jura-Cretaceous.

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[*] It is possible that the rocks at cape Beaufort may on further research prove to be older than Jura-Cretaceous, but for the present it seems best to include them in the Corwin series.

[†] A full description of these collections will appear in Doctor Ward's second paper on the Older Mesozoic floras to be published by the U. S. Geological Survey.

The forms from near Wainright inlet are as follows:

Nageiopsis longifolia Font. Older Potomac of Virginia (Lower Cretaceous).
Podozamites distantinervis Font. Older Potomac of Virginia (Lower Cretaceous).
Baiera gracilis (Bean) Bunbury. Oolitic of Yorkshire, England (Jurassic).

ANAKTOOVUK SERIES (LOWER CRETACEOUS)

Character and occurrence.—The Anaktoovuk series, named from the river on which it occurs, forms the southern or principal part of the gently rolling Anaktoovuk plateau along the north side of the Endicott range, which it meets at an elevation of about 2,500 feet, as shown in plate 41. Here its inland edge seems to rest unconformably on the Devonian limestone of the Lisburne formation, from whence the series extends northward a distance of about 60 miles, where it unconformably meets and underlies the Nanushuk series. Eastward the Anaktoovuk series is probably soon limited by the front of the Paleozoic range, while to the westward and northward it probably embraces and constitutes the so-called Meade River mountains, and, continuing northwestward, may extend to the Arctic coast. The series consists essentially of heavy-bedded impure, dark-gray, or dirty-greenish, fine or medium grained sandstone. An inspection of their mineral constituents shows that the sediments are obviously derived from the Paleozoic rocks of the range, and especially from the Stuver series.

Structure.—The strike or trend of the Anaktoovuk series is approximately east and west, with the prevailing dip generally north, so that, broadly considered, the structure is in the main monoclinal. Following deposition, the beds were gradually uplifted and thrown into gentle anticlinal and synclinal folds, probably in sympathy with the later of the mountain-building forces that were exerted in the range to the south. Two systems of jointing frequently traverse the rocks. Of these, what seems to be the dominant or major system trends northwest and southeast, with dip steeply southward at an angle of 80 degrees, while the secondary or minor traverses the rocks at nearly right angles to the major, with dip 80 degrees southeast, both systems agreeing in general trend with those of the Paleozoics in the range to the south.

Age.—The series is determined on fossil evidence to be Lower Cretaceous, constituting the typical Aucella beds of Alaska. Remains were collected at 8 miles north of the foot of the mountains and successively at other points in crossing the series. Of these forms, the principal or most characteristic, as determined by Doctor Stanton, are *Aucella crassocollis*

Keyserling, or a closely related form and undoubtedly of Lower Cretaceous age. The series is to be correlated with the Koyukuk series, to be next described, though the lithologic difference between the two series is somewhat marked.

KOYUKUK SERIES (LOWER CRETACEOUS)

Character and occurrence.—The Koyukuk series constitutes the southern 45 miles of the section lying principally between the 66th parallel and the Arctic circle, on the Koyukuk river. The series, however, is known to extend much farther southwestward, and may with further discovery prove to have a very wide extent over the Koyukuk basin. The rocks of the series consist of impure pink and reddish limestone, dark shale, slate, and some sandstone or arkose, all more or less associated with or intruded by igneous rocks, denoting volcanic activity during and subsequent to Lower Cretaceous time. The series is represented as limited on the northeast by the Bergman series, which in a general way it seems to underlie, but may later be found to be closely connected with it in point of geologic age. Owing to the various breaks in the sequence of outcrops, and the changed attitude of the rocks, no estimate of the thickness of the Koyukuk series can be given as yet. It may be noted, however, that at the point where the fossils were collected, near the southern end of the section, the limestone alone exhibits a thickness of about 800 feet.

Structure.—The series has been variously disturbed by folding and some faulting, but the prevailing dip seems to be northward, roughly speaking, at an angle of 40 degrees. A profuse jointing trends nearly north 25 degrees west and dips steeply northeast, while a well marked cleavage dips 75 degrees southeast.

Age.—The age of the Koyukuk series is supposed to be the same as that of the Anaktoovuk series, Lower Cretaceous. This assignment is based on the evidence of fossils collected in the impure limestone near the southern end of the section, and which were found to be undoubtedly of Lower Cretaceous age by the presence of *Aucella crassicollis* Keyserling, thus correlating the Koyukuk series with the Anaktoovuk series, both containing Aucella beds typical of Lower Cretaceous in Alaska.

BERGMAN SERIES (CRETACEOUS)

Character and occurrence.—The series consists of a comparatively uniform group of rocks, covering a large area in the Koyukuk basin and forming in large part the rolling Koyukuk upland already noted. It succeeds the Koyukuk series on the north, and has a north and south extent of about 60 or 70 miles. On the north it rests unconformably on the schists of the Totsen series at the base of the mountains, while on the south it is apparently infolded with the Koyukuk series, which it is supposed to closely succeed in geologic age. The series consists essentially of thin-bedded or medium-bedded impure gray or brownish sandstones and dark slates, with some dark shale and occasional conglomerates; but along the north it is bordered by a belt of conglomerate from several to 10 miles in width, which apparently represents the basal member of the series. The series is undoubtedly of sedimentary origin, but the sediments have been largely derived from igneous rocks, as shown by the generally feldspathic constituents of the sandstone and by the presence of basaltic or diabasic and granitic pebbles in the conglomerate on the Alatna river and at Lookout mountain. The supposed basal conglomerate on the north is, however, composed essentially of limestone and mica-schist materials derived from the Skajit formation and the Totsen series. An accurate estimate of the thickness of the series cannot be given. From a general impression, however, it seems safe to indicate that it will probably amount to 2,000 feet.

Structure.—The series has been considerably folded and somewhat faulted, but to a much less degree than the Koyukuk series. A pronounced jointing trends northwest and southeast and dips 80 degrees northeast. A minor jointing trends north and south and dips east at an angle of 80 degrees. On the north, where the series apparently rests against the Totsen series, the dip is about 45 degrees south.

Age.—No fossils beyond undeterminable lignitic plant remains have thus far been found in the Bergman series. From its apparent close relations, however, to the Koyukuk series it seems that the Bergman series is probably Cretaceous. Lithologically it bears a strong resemblance to the Anaktoovuk series to the north of the range.

NANUSHUK SERIES (UPPER CRETACEOUS)

Character and occurrence.—On the north, the Nanushuk series succeeds and seems to unconformably overlie the Anaktoovuk series, while northward it disappears beneath the Tertiary rocks of the coastal plain, with which its relations are also apparently unconformable. Its width in a north and south direction is about 30 miles, while its east and west distribution is probably somewhat similar to that of the Anaktoovuk series. The rocks are mainly thin bedded gray and brown sandstone, generally fine grained and sometimes friable, slate-colored arenaceous and impure fossiliferous limestone, dark shale or mud rock, soft uncleaved slate, fine grained gray quartzite, drab-colored chert, and bituminous coal.

Where best observed on the Anaktoovuk, the beds strike nearly east and west and dip south at an angle of 80 degrees, but the prevailing dip of the series, however, is probably north. The series has been somewhat folded and slightly faulted, and it is cut by a pronounced system of jointing or sheeting along planes approximately horizontal.

Age.—On fossil evidence, the series is assigned to the Upper Cretaceous by Doctor Stanton, who has identified the following forms :

Inoceramus, a large species.
Astarte, numerous.
Nucula, numerous specimens.
Avicula.
Pectunculus, several specimens.
Thracia.
Tellina, two species.
Siliqua.
Modiola.
Scaphites.
Hammonia.

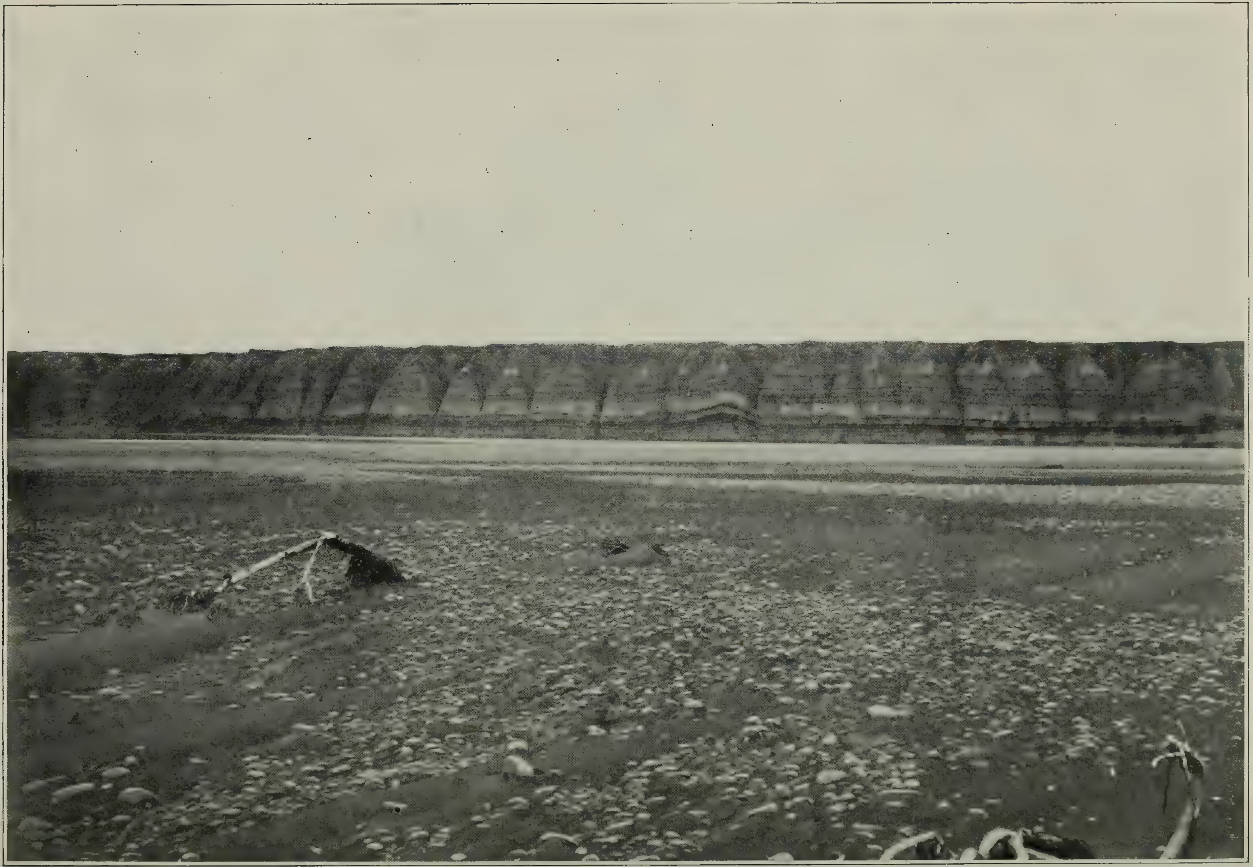
UPPER CRETACEOUS ON THE KOYUKUK

To the south of the Endicott range and south of the limits of the section in the Koyukuk region, Upper Cretaceous has also been found. Of the collection made here by the writer, Doctor Stanton reports the following forms and refers the beds to about the same horizon as the early Chico :

Ostrea.
Anomya.
Mytilus.
Pectunculus cf. *P. veatchii* Gabb.
Opir ?
Lucina.
Trigonia cf. *T. leæna* Gabb.
Corbula.
Actæonella cf. *A. oviformis* Gabb.

Tertiary—Colville Series

This series of Tertiary terranes succeeds the Upper Cretaceous or Nanushuk series on the north, forming a flat tundra country or coastal plane. It extends from some distance above the mouth of the Anaktoovuk 100 miles northeastward to the Arctic coast. The inland edge of the coastal plain has an elevation of about 800 feet, from which, with very gradual slope, the surface descends approximately to sealevel at the coast. The series consists principally of heavy bedded, partially consolidated silts or mud rock, with intercalated harder layers of soft sandstone, limestone, shale, lignite, and unconsolidated silts (see plate 43). The sediments are conspicuously derived from the preceding Cretaceous formations and the Paleozoics of the Endicott range. So far as observed during the past season, the series is separable into two parts—Oligocene and Pliocene. The portion assigned to the Oligocene is best exposed along the Colville in the region of the mouth of the Anaktoovuk. Here



COLVILLE RIVER AND BLUFFS

it constitutes the lower three-fourths, or 150 feet, of the section exposed, and includes all the above noted rocks, excepting the unconsolidated silts. These latter are free from lignitic remains, and on the basis of their invertebrate fossils are assigned to the Pliocene. Accordingly the Pliocene, so far as observed, consists of nearly horizontal stratified beds of mostly fine gray slate and ash-colored calcareous silts, containing faunal remains. By conservative estimate the thickness of the Colville series is probably 500 or 600 feet, and, judging from topography, it probably has a very great extent in an east and west direction, possibly reaching the coast in the region south of point Barrow.

Though the series, as shown in plate 43, has been slightly faulted, folded, and crowded from the inland direction, it is on the whole but little disturbed. The beds lie nearly horizontal or dip gently north or northwestward at a low angle of 4 or 5 degrees, as shown in plate 43. The lower part of the series is supposed to be Oligocene on the ground of the presence of the lignite beds and vegetable remains it contains and its resemblance to known similar beds occurring elsewhere in Alaska, and also on the ground of its relation to the Pliocene silts which it immediately underlies. Lignitic shale examined by Doctor Dall is supposed to contain the form of *Sequoia langsdorffi* Heer. The upper part of the series is assigned to the Pliocene on the basis of its fossil forms, which have been reported by Doctor Dall as follows:

Chrysodomus, 2 species.
Amauropsis.
Tachyrhynchus polaris Beck.
Macoma frigida Hanley.
Macoma incongrua von Martens.
Astarte semisulcata Leach (possibly Quaternary intrusion).
Saxicava arctica L.

PLEISTOCENE

THE DEPOSITS

Besides the present stream gravels, the most important Pleistocene deposits traversed by the section, but not represented on it by reason of the small scale, are the Goobic sands, glacial deposits, ground ice, and muck.

GOOBIC SANDS

This formation is a surficial deposit of brownish sand or loam about 10 or 15 feet in thickness, which, like a continuous mantle, overlies the beds of the Colville series unconformably, as shown in plate 43 at the top of the bluff just above the light-colored triangular exposures of Pliocene. It seems to be distinct from the Colville series and to be persistent over a wide area of country. It not only forms the surficial terrane of the coastal plain along the Colville, but seems to be persistent along the coast from the mouth of the Colville westward, while its inland margin seems to overlap onto the Upper Cretaceous of the Nanushuk series. In character, the material composing the deposit is fine-grained and, on the whole, uniform or homogeneous. Its description as fine sand, with an admixture of considerable silts or earthy material, perhaps best conveys an idea of the texture of the deposit. In some localities it seems to be more distinctly sandy toward the base and earthy toward the top, where it sometimes grades into from one to several feet of dark-brown or black humus or muck, clothed at the surface with moss and a little grass. The deposit is ordinarily free from gravel, but in several instances pebbles ranging from mere grains to as large as one-fourth of an inch in diameter were found. These consist essentially of dark flint and may be characterized as subangular. They are sometimes roughened or grooved, as if wind-worn. They occur very scatteringly indeed. It should be noted, however, that in some instances a very fine gravel or grit occasionally intervenes between the base of the deposit and the underlying Tertiary beds.

The deposit, as a rule, is structureless or devoid of stratification. In only a few instances were indications of stratification observed, and this, though it was faint and indefinite, seemed to dip at a considerable angle and was accompanied by indistinct crossbedding. Weathered faces of the deposit frequently present the appearance of unpronounced stratification; but on careful removal or cutting away of this weathered part, in search of more conclusive evidence, the material is found to be structureless. Owing to its surficial and widespread occurrence, the homogeneity of its materials and its structureless character, and the difficulty of explaining its origin, for want of a better term in field-work the deposit was called loess. After further consideration, however, it is feared that the retention of the term would be undesirable, for which reason the deposit is here given the name of Goobic sands.

To account for the origin of the Goobic sands, the following causes have suggested themselves, namely, glacial, fluviatile, delta, eolian, marine or beach, none of which alone seems to afford a satisfactory explanation. It is probable, however, that the fluviatile delta theory, in conjunction with shallow coastal conditions and intense Arctic freezing, may prove the most tenable.

GLACIAL MATERIAL

While there is no evidence of truly regional glaciation in northern Alaska, it is now known that ice action has been far more extensive than has been generally supposed by geologists who have drawn their deductions concerning this remote region from observations made on a trip down the Yukon or along the western coast. The Endicott mountains, as illustrated in the topography shown in plate 42, do not seem, so far as observed, to have been overridden by an ice-sheet, but in the valleys nearly everywhere there is such evidence of ice drainage as striæ, terminal moraines, and deposits of till. The breeding ground for these glaciers was in the Endicott range, with the zone of maximum accumulation probably somewhat north of its median line. Here the mountains were doubtless largely overlain by an ice cap or névé, but the ice movement was confined essentially to the drainageways leading off to the north and to the south. But on the north slope of the range the ice seems to have moved off, at least locally, in a continuous sheet or small regional glacier, with its front reaching north beyond Willow creek, some 35 or 40 miles beyond the base of the mountains. This is evidenced by the more or less continuous till sheet overspreading the entire region and by deposits of drift and erratics on the highest portion of the Cretaceous plateau. In the valleys this sheet or ground moraine attains a thickness of about 150 feet. From the edge of the ice-sheet ice drainage in the form of valley glaciers continued about 40 miles farther northward, to near the mouth of the Anaktoovuk, but none crossed the Colville, whose drainageway does not seem to have been interrupted since the Tertiary.'

On the south of the Koyukuk basin similar, but not so pronounced, evidence extends to beyond the Arctic circle, a distance of 50 or more miles southward from the base of the range. Here, however, the glacial phenomena, so far as observed, are more of the valley glacier type, but the deposits are undoubtedly till and contain striated pebbles of distinctly glacial type. Along the route of traverse, omitting the mound-like remnant, about 300 feet in diameter and 60 feet in height, near the middle of the range in John River valley, the glacial ice has disappeared from the country.

GROUND ICE, MARSH, MUCK, MUD FLATS, ETCETERA

The northern 30 miles of the section, between the point where the Tertiary bluffs of the Colville series leave the river, lie in marsh flats whose inland half is continuous with the ground abandoned by the Colville river in its lateral migration or drifting of 30 or more miles westward and its simultaneous down-cutting into the Tertiary terranes, while the coastal half lies in the Colville delta, both of which features, however, slope down to low marshes, and finally expansive tidal mud flats and bars at the coast. Inland, these abandoned flats are probably underlain, in part at least, by the lower beds of the Colville series; but where their edges form the banks of the river at 10 to 20 miles from the coast they seem to be composed of dark muck and ground ice for a depth of 10 or 15 feet below the surface.

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GEOLOGICAL RECONNAISSANCES IN SOUTHEASTERN ALASKA*

BY ALFRED HULSE BROOKS

(*Presented before the Society January 2, 1902*)

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INTRODUCTION

During the summer of 1901 the writer, assisted by Mr Corey C. Brayton, spent about two months in making a preliminary reconnaissance of the Ketchikan mining district, and later about one month in a more general reconnaissance of other parts of southeastern Alaska. The results of this work are to be published by the U. S. Geological Survey in a report entitled "Preliminary Report on the Ketchikan Mining District of Southeastern Alaska." In view of the little that is known of this region, it has seemed worth while to abstract the more important conclusions bearing on the general geology of the region.

A few small areas in this region have been studied in some detail and many facts have been gathered, but almost no attempt has been made to correlate them. The work of the Canadian geologists, however, near the boundary and in British Columbia has added to the knowledge of the stratigraphic succession and of some of the larger structural features. Every worker in the field must acknowledge his indebtedness to Dr George M. Dawson,† who has contributed so much to our knowledge of the geology and resources of the northwestern part of our continent.

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*Published by permission of the Director of the United States Geological Survey.

†Geo. M. Dawson: Report on an exploration in the Yukon district, N. W. T., and adjacent portions of British Columbia. Ann. Rept. Geol. and Nat. Hist. Survey, Canada, 1887, part B.

Portions of the region have also been the subject of investigations by Blake,* Hayes,† Dall,‡ Becker,§ Russell,|| Spurr,¶ Reid,** Cushing,†† and the writer.‡‡ There are a number of others who have contributed to our knowledge of the glaciers of the region.

GEOGRAPHY

The panhandle of the territory, extending southeastward from mount Saint Elias, is usually called southeastern Alaska. This coastal belt and its contiguous islands have an area of nearly 40,000 square miles. It is included between 54 degrees 30 minutes and 60 degrees 30 minutes parallels of latitude and the 130th and 141st meridians of longitude. That portion which is more especially the subject of this sketch lies to the southeast of Cross sound and Glacier bay, and includes an area of about 20,000 square miles.

Alaska is divisible into four geographic provinces, corresponding to and, broadly speaking, coextensive with those of western Canada and the United States. The westernmost of these includes a mountainous belt, which, in conformity to Major Powell's §§ nomenclature, may be called the Pacific Mountain system. East of this is the Plateau region, bounded to the east and north by the third province, which is formed by the northern and western extension of the Rocky Mountain system, and to the east and north of the Rocky mountains is the fourth province, comprising the Plains region. Southeastern Alaska lies entirely

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* William P. Blake: Topographical and geological features of the northwest coast of America. Am. Jour. Sci., 2d series, vol. xlv, 1868, pp. 242–247.

Alaska Territory, Geology of. U. S. Coast Survey, Report for 1867, pp. 281–290.

† C. Willard Hayes: An expedition through the Yukon district. Nat. Geog. Mag., vol. iv. pp. 99–162.

The writer is under obligations to Doctor Hayes for the use of unpublished notes.

‡ William H. Dall: Coal and lignites of Alaska. Seventeenth Ann. Rept. U. S. Geol. Survey, part i, pp. 763–908.

§ George F. Becker: Gold fields of Southern Alaska. Eighteenth Ann. Rept. U. S. Geol. Survey, part iii, pp. 1–86.

|| I. C. Russell: Expedition to Mount Saint Elias. Nat. Geog. Mag., vol. iii, 1891–'92.

Second expedition to Saint Elias. Thirteenth Ann. Rept. U. S. Geol. Survey, part iii, pp. 1–91.

¶ J. E. Spurr: Geology of the Yukon gold district. Eighteenth Ann. Rept. U. S. Geol. Survey, part iii, pp. 87–392.

** H. F. Reid: Studies of the Muir glacier. Nat. Geog. Mag., vol. iv, 1892–'93.

†† H. P. Cushing: Notes on the geology in the vicinity of the Muir glacier. Nat. Geog. Mag., vol. iv, 1892–'93; Am. Geol., vol. viii, pp. 207–230.

‡‡ Reconnaissance in Tanana and White River Basins, Alaska, in 1898. Twentieth Ann. Rept. U. S. Geol. Survey, part vii, pp. 425–494.

Reconnaissance from Pyramid Harbor to Eagle City, Alaska. Twenty-first Ann. Rept. U. S. Geol. Survey, part ii, pp. 331–391.

§§ Major Powell included under "Pacific Mountains" ranges lying west of the Basin ranges in the United States. The term "Pacific Mountain system" is intended to include all of the mountains of North America which lie contiguous to the Pacific ocean. Comp. Monograph Nat. Geog. Soc.

within the first of these provinces. The Pacific Mountain system includes four important ranges, whose axes are parallel to each other and to the coast line, with numerous inferior transverse lines of height. Of these the Coast range, the Saint Elias range, and the Aleutian range lie adjacent to the coast, while the Alaskan range is inland and forms the northern boundary of the system. The two latter lie without the region under discussion, and will not be further considered.

The so-called Coast range extends from near the boundary of Washington northward through British Columbia into southeastern Alaska. In British Columbia it has a width of about 100 miles, which decreases to the northward. Its peaks vary in altitude from 7,000 to 8,000 feet. Following the coastline for nearly 900 miles, it passes behind the Saint Elias range near the head of Lynn canal, beyond which it can be traced northward, but with decreasing altitudes, and gradually loses its distinctiveness, finally merging with the interior plateau. The Coast range has no distinct crest line, but is, as Doctors Dawson and Hayes have shown, an irregular aggregate of mountains, whose summits mark an elevated plateau and whose limits are often ill defined. Inland it locally merges with the interior plateau, and on the coast side it is not always well differentiated from the mountains of the Alexander archipelago.

Westward from Cross sound the Saint Elias range forms the coastal feature of Alaska, and is extended to the southeast mountainous Alexander archipelago. Near mount Saint Elias the range has a width of about 100 miles, but it narrows down in both directions. Near Cross sound the Fairweather group of mountains in the Saint Elias range reach altitudes of over 15,000 feet. Toward the west it increases in height and complexity, culminating in mounts Saint Elias and Logan, 18,060 and 19,500 feet in height. The mountains of the Alexander archipelago cannot be said to form any well defined range. On Baranof island are mountains reaching altitudes of 3,000 to 4,000 feet. On Prince of Wales island there are also many peaks which rise to these altitudes, but they are irregularly distributed. In general, the trend of these mountain groups is in a northwest-southeast direction, parallel to the coast line and to the Coast range. There is but little topographic data available in this region except the contour of the actual shoreline.

The coastline of this part of Alaska is very irregular, the shore being marked by many deep embayments and islands. The shores are usually very abrupt, and the deep water lies close to the land.

Southeast of Glacier bay over half of the land area is included in the islands of the Alexander archipelago. The longer axes of the larger islands have a rough parallelism to each and to the general trend of the mainland coast. The otherwise smooth coastlines of the island are broken by numerous fiords similar to those which penetrate deeply into the adjacent Coast range. The islands are separated from each other and the mainland by deep and often very narrow waterways. Some of these, like Lynn canal, penetrate far inland. An examination of a map will show that these features have a more or less parallel arrangement, and attention will be drawn to the fact elsewhere that the direction of these channels is consequent on structural lines in the bed rock.

In southeastern Alaska four rivers of considerable size—the Alsek, Chilkat, Taku, and Stikine—have their sources in the Interior Plateau region, and reach the sea after traversing the coastal ranges. The Chilkat flows through the depression which separates the northern extension of the Coast range and the Saint Elias mountains. There are many minor streams on the mainland of southeastern Alaska which have their sources within the Coast range. The drainage of the islands of the Alexander archipelago is usually carried to the sea by small streams. The lack of topographic maps makes it impossible to describe them in any detail.

GEOLOGY

STRATIGRAPHY

While but few of the details of the geology of southeastern Alaska are known, and even the general succession of beds is very much in doubt, yet the distribution of certain lithologic types is fairly well established. The general trend of the rocks is in a northwest and southeast direction parallel to the coastline. There are certain lithologic types occurring as belts running parallel to this strike, which seem to persist with rather remarkable uniformity from Dixons entrance to Lynn canal and Icy straits.

The granite which forms the Coast range is the best defined of the lithologic belts, and has been traced, practically without interruption, from Portland canal to the head of Lynn canal. East of the granite belt are a series of quartz-schists and limestones, which seem to be fairly persistent from Bennett lake southward. These are in turn succeeded to the eastward and unconformably overlain by younger sediments. To the west of the granite is a belt of black phyllites and arenaceous schists, which are locally much metamorphosed and include many greenstone schists. These are fairly persistent throughout southeastern Alaska. To the west of the phyllite belt bluish limestones have been observed at a number of localities. This belt has not been so well traced. Still farther west is a belt of white and blue crystalline limestone associated with phyllites. These rocks are very persistent, and

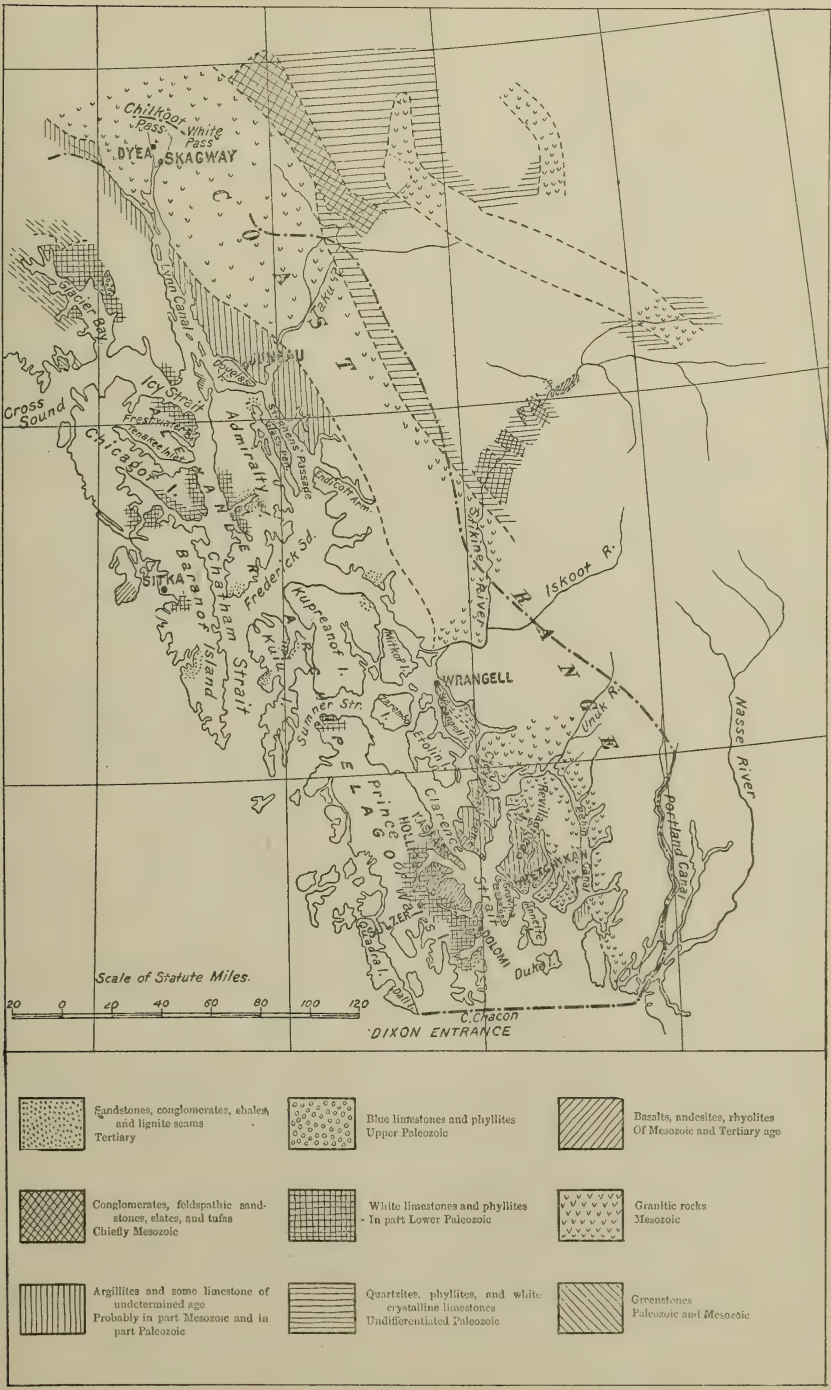
Chilkoot Pass
White Pass
DYEA
SKAGWAY
C O A S T
R A N G E
Lynn Canal
Glacier Bay
JUNEAU
Douglas
Taku R.
Cross Sound
Icy Strait
Freshwater
Tenakee Inlet
Chicagof I.
A L E X A N D E R
Admiralty I.
Stephens Passage
Endicott Arm
Frederick Sd.
SITKA
Baranof Island
Chatham Strait
Kupreanof I.
Kuiu I.
A R C H I P E L A G O
Mitkof I.
Stikine River
Iskoot R.
WRANGELL
Wrangell I.
Sumner Str.
Zarembo I.
Etolin I.
Unuk R.
Nasse River
Portland Canal
Clarence Strait
Prince of Wales I.
HOLLIS
KASAAN
Revillagigedo I.
KETCHIKAN
Behm Canal
Gravina
Annette I.
Duke I.
SULZER
DOLOMI
Dall I.
C. Chacon
DIXON ENTRANCE
Scale of Statute Miles.
20 0 20 40 60 80 100 120
Sandstones, conglomerates, shales and lignite seams Tertiary
Blue limestones and phyllites Upper Paleozoic
Basalts, andesites, rhyolites Of Mesozoic and Tertiary age
Conglomerates, feldspathic sandstones, slates, and tufas Chiefly Mesozoic
White limestones and phyllites In part Lower Paleozoic
Granitic rocks Mesozoic
Argillites and some limestone of undetermined age Probably in part Mesozoic and in part Paleozoic
Quartzites, phyllites, and white crystalline limestones Undifferentiated Paleozoic
Greenstones Paleozoic and Mesozoic

FIGURE 1.—*Geological Map of Southeastern Alaska.*

occupy large areas in Prince of Wales, Baranof, Chichagof, and Admiralty islands.

These four formations, (1) the white limestone and phyllite, (2) the blue limestones, (3) the black phyllite and arenaceous schists, and (4) the Coast Range granite, form the country rock of the larger part of southeastern Alaska. There are also younger sediments, volcanic rocks, and various types of intrusives in this field.

The oldest beds of the region in which fossils have been found are the limestone outcropping on the shores of Glacier bay.* Professor Cushing found a few fossils in this limestone, which were determined as Paleozoic by Professor H. S. Williams. Later, on the evidence presented by these fossils and on that of coral collected from the Dirt glacier by Professor J. J. Stevenson, these limestones were assigned to the Carboniferous.† It will be shown below that the latter fossil is from an entirely different horizon. Through the kindness of Professor Williams the Drake Island material was submitted to Mr Charles Schuchert, to whom the writer is indebted for the following report on three fossils:

"I have examined the Drake Island material and find a large *Leperditia* of the *L. baltica* group.

"*Megalomus* sp. undet.; sections of a very large species very similar to *M. canadensis.*

"*Hormotoma* sections, like several found in the Guelph of Ontario.

"The species on which one can depend for age determination is the *Leperditia.* These large species of *Leperditia* cease with the basal beds of the American Devonian (Lower Pentamerus = Coeymans), but their greatest abundance is in the Wenlock and Dudley horizons of Europe. The Glacier Bay species is unmistakably related to the *L. baltica* of the Upper Silurian. Further, it is not related to the large Lower Silurian forms of the *L. flabulites* group, and this is again shown by the presence of very large bivalve shells, which I take to be of the genus *Megalomus,* a fossil so characteristic of the late Upper Silurian. Even if the large shells are not *Megalomus* these *Leperditias* alone prove that the limestone can not be younger than the late Upper Silurian. It is true that the genus *Leperditia* is stated to occur as late as Lower Carboniferous time (*L. carbonaria* Hall, *L. nicklesi* Ulrich), but all the Devonian and Carboniferous species are minute forms, and if they do not belong to other genera, which seems probable, they certainly can not be included in the *L. baltica* group of *Leperditia.*

"The coral identified as *Lonsdaleia* comes from another locality (Dirt glacier) more than fifteen miles away, and can not be included in the Drake Island fauna. To this locality one should for the present restrict the type section for the 'Glacier Bay limestone,' for the reasons above given, and for the further one that the coral was not found in situ."

Reid and Cushing found argillites underlying the limestones conformably and both forming a closely folded series. This series has been identified by the writer at a number of localities to the south, and forms the westernmost of the lithologic belts which have been referred to.

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* Nat. Geog. Mag., vol. iv, p. 59; 16th Ann. Rept., part i, p. 433.

† Sixteenth Ann. Rept., part i, p. 434.

Reference has already been made to a coral which was found on the moraine of Dirt glacier by Professor Stevenson. The following is quoted from Professor Stevenson's description :*

> "The Dirt glacier or first western tributary of the Muir must head up against an outcrop of this limestone, for one of the passengers on our vessel picked up a form like *Acervularia*, which, taken in connection with some *Leperditia* obtained by Mr Cushing in 1890 (Drake island), tends to show that the limestone (Glacier Bay limestone) is not younger than Middle Devonian."

Through the courtesy of Professor Williams, Mr Schuchert was enabled to examine, too, the coral secured by Professor Stevenson, and he reports as follows:

> "Later this coral was sent to Professor Williams, and Cushing reports that he identified it as a *Lonsdaleia*, 'and regards it as demonstrative of the Carboniferous age of the horizon whence it came.'
>
> "I agree with Stevenson that the coral in question is an *Acervularia*, since it has no *columella*, as is demanded for species of *Lonsdaleia*. It is a species near *A. davidsoni*, a coral so characteristic of the Middle Devonian of the Mississippi valley. It may prove to be a new species when sections are made. The genus *Acervularia*, however, is unknown above the Devonian. Another *Acervularia* is known from the Mackenzie River country (*Cyathophyllum arcticum* Meek), so that the genus may be expected to turn up elsewhere in the far north.
>
> "Since *Acervularia* of the type *A. davidsoni* is so characteristic of the Middle Devonian, it seems safe to assume that beds of this age occur in the Glacier Bay region, and that it is the same general horizon discovered the past summer by Mr Brooks at Long Island, Kasaan bay, Prince of Wales island."

According to Mr Schuchert, then, this coral is from a bed which is an entirely different horizon from the limestones at Drake island, which he determined as Silurian. This evidence points to the conclusion that there is a younger limestone in the Glacier Bay region which is of Devonian age. This limestone, however, has not been identified at any other locality in the northern part of the region under discussion.

In the southern islands of the Alexander archipelago Devonian beds have been found at several localities. Mr Schuchert identified as Devonian † some fossils contained in a white crystalline limestone collected at Saginaw bay, Kuiu island, by Mr Brightman. It is interesting to note that some fragments of sandstone from this same locality contain Upper Carboniferous fossils. This is the only locality in southeastern Alaska where this horizon has been identified.

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*The Scottish Geog. Mag., vol. ix, 1893, p. 70.

†Charles Schuchert: "Report on Paleozoic Fossils from Alaska." Appendix ii, Coals and Lignites of Alaska, Seventeenth Ann. Rept., part i, p. 902.

In the Ketchikan district, Middle Devonian fossils were found at Long island, Kasaan bay, Prince of Wales island, and at Vallenas bay, Gravina island. The presence of Devonian fossils in these widely separated localities goes to show that this period is probably well represented in southeastern Alaska. At the Prince of Wales Island locality the Devonian beds are almost entirely unaltered, and this rather unsafe criterion has been used to differentiate them from the older white crystalline limestone series. When more detailed examinations have been made, it may be found that some of the crystalline limestones are of Devonian age. These rocks of Devonian and Carboniferous age form the second of the lithologic belts.

The third belt in which the rocks have lithologic similarity lies west of and adjacent to the Coast range. It consists of argillites, with some limestones and a large amount of intrusive greenstone. It has been recognized by the writer in the southern province and again in the northern part of the province. Its age has not been determined, but it probably includes both Carboniferous and Triassic rocks. Near the contact with the granite, which latter is intrusive, it is often considerably altered.

The granite belt which forms the Coast range has already been referred to. It is a batholitic intrusion of great extent which has been traced for 800 or 900 miles. This intrusion probably took place in Triassic times. While most of the granite is massive, it in places includes some schistose and gneissoid phases. There are also outlying masses of granite both east and west of the Coast range.

The older sediments west of the Coast range have been differentiated into three groups, of which two are Paleozoic and one is probably in part Paleozoic and in part Mesozoic. The corresponding series east of the Coast range are all grouped together as Paleozoic. The writer has only studied them along one section, and found it impossible to differentiate them.

In the southern part of the Alexander archipelago a heavy conglomerate was found overlying Upper Paleozoic rocks unconformably. These are believed to be Mesozoic and probably Cretaceous, though no fossils were found in them. East of the Coast range and in the Queen Charlotte islands to the south Dawson and others have found beds of similar character, which are of Lower Cretaceous age.

Large areas of extrusive rocks, probably of Mesozoic age (Cretaceous ?), were observed by the writer on Prince of Wales island. These are chiefly of andesitic character, and are closely associated with intrusive rocks, from which they can not always be easily differentiated.

Tertiary sediments have been noted at a number of localities. They consist of conglomerates, sandstones, and shales, usually slightly indurated and only gently folded. They have been studied in some detail by Dall,* who determined them as belonging to the Kenai division of the Oligocene. At Lituya bay the Kenai beds are overlain by Astoria beds (Miocene).

At Sitka some highly feldspathic sandstones were observed, whose stratigraphic position was not determined. These were described by Becker † as pyroclastic diorites. In thin-section they show many minerals derived from crystalline rocks. In the field they are sometimes massive, but more often plainly bedded. Their stratigraphic position has not been determined, but they may provisionally be assigned to the Tertiary.

In the northern part of the Alexander archipelago there are some lavas, probably of Pleistocene age, but which may be in part Tertiary.

Greenstones are the most widely distributed of the igneous rocks in the province. This term is made to include various igneous rocks of a rather basic character and of varied composition. The oldest intrusion seems to have taken place in early Paleozoic times, and was of a diabasic nature. These older greenstones are usually schistose. Diorites and quartz-diorites occur both massive and schistose. Among the less common types are gabbros, pyroxenites, and amphibolites. The older greenstones are usually much altered and made up chiefly of secondary minerals. In the Ketchikan district the diabases form the latest intrusives. Syenites have been found at a number of localities, notably at the Treadwell mine near Juneau.

SUMMARY

In the province under discussion Paleozoic terranes, ranging from Silurian or older to the Carboniferous, have an extensive development. Large masses of greenstones are intruded in the lowest members of the Paleozoic succession. In part of the region, at least, a stratigraphic break is known to occur somewhere in the Devonian. A series of argillites occur which seem to belong to the Upper Paleozoic horizons and Lower Mesozoic, but whose stratigraphic position was not determined. Mesozoic time is represented in one part of the region by sedimentary strata, whose basal member is a conglomerate, overlying the Paleozoic rocks unconformably, and in another part by large extrusions of volcanic rocks. Very large injections of granite took place along the Coast Range axis, probably during middle or latter Mesozoic times, and in smaller masses elsewhere in the region. The Tertiary is represented by lignite-bearing sediments of Oligocene age, which are only slightly disturbed or indurated. Some volcanic rocks have been extruded in post-Tertiary times. Besides these, dikes of various rock types are present in all the pre-Tertiary beds.

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* Coals and lignites of Alaska. 18th Ann. Rept. U. S. Geol. Survey.

† George F. Becker: Gold fields of southern Alaska. 18th Ann. Rept., part iii, p. 43.

The earliest epoch of intense disturbance was in pre-Devonian times, and was accompanied by large intrusions of basic igneous rocks. The next period of metamorphism was in middle Mesozoic times, when the intrusion of the granite of the Coast range took place. The alteration of the sediments adjacent to the mass of granular igneous rock is assigned jointly to contact metamorphism and the mechanical effect of injections. The granite itself shows the effect of deformation by which it has been locally changed to gneiss and mica-schist. No evidence of any post-Tertiary disturbances has been found.

The history of the deformation of the rocks of the region is a complex one, and has not yet been deciphered. In the western belt of Lower Paleozoic beds the strata are intensly metamorphosed and deformed. To the east in the Upper Paleozoic beds dynamic action has been less, while still farther to the east in the belt of argillites, the metamorphic action has again been intense. To the east of the Coast range the Paleozoic rocks have all suffered about the same degree of alteration, with the exception of those which lie immediately adjacent to the intrusive granites. It is evident that the observed metamorphism has been of two kinds, assignable to different causes—the regional metamorphism, which is due to deformation; and the contact metamorphism, which has been brought about by the intrusion of igneous rocks.

The phenomena of contact metamorphism are commonly regarded as confined to chemical effects produced by the heat and accompanying gases of igneous intrusions, but many cases are on record where the mechanical effect caused by the pressure of the invading rock has been of great importance. Such is the case in the vicinity of the granite masses of the Coast range, where the mechanical alteration of the rocks is quite comparable to the regional metamorphism noted in neighboring localities; and, since the intrusion occurred after the greatest regional disturbance, the effects of the latter have been to a certain extent obscured by the former.

There are three zones in the province which are marked by more or less intense metamorphism. The one includes the rocks of the Lower Paleozoic beds, extending through the western group of the Alexander archipelago, while the other two lie on either side and adjacent to the granite of the Coast range. The two westernmost of these zones, in the southern part of the region at least, are separated by a belt of Upper Paleozoic beds, which are folded, but only slightly indurated, while the Coast Range granite separates the two eastern zones.

In the western belt the sediments are intensely folded and plicated, and are generally metamorphosed to such an extent that the limestones appear in the form of marble and the argillaceous strata as phyllites. The broad structural lines are in general parallel to the northwest and southeast, but the axes of minor folds are extremely variable in direction.

The period of mountain-building during which these effects were produced is the earliest of which we have any record in southeastern Alaska, and it was during this epoch that the injection of igneous rocks included under the designation "greenstone" commenced. Other intrusions of similar basic rocks are known to have occurred also at later dates, as shown by their relatively massive character when compared with certain highly sheared phases of the greenstones.

In the southern part of the province the Paleozoic sedimentation was interrupted by mountain-building, and also a period of erosion ensued, probably in early Devonian times. The Devonian beds are much less altered than those of the Lower Paleozoic, and the folding which they exhibit is of a broad, open type. Tracing these Devonian beds eastward, they are found to become metamorphosed as the zone of the Coast Range intrusives is approached.

The two eastern zones of metamorphic strata which lie adjacent to the intrusive granite belt of the Coast range may be assigned, in part at least, to contact metamorphism. Most of the rocks on the west side of the range are argillites, which are much altered. To the east of the range there is a succession of sediments whose basal members are also considerably altered. This metamorphism is in part plainly due to igneous contact, but must in part be assigned to the mechanical stress brought about by the intrusion of the granite. The intrusion of the granite has been shown to be Mesozoic and probably post-Triassic. The evidences of contact metamorphism are the minerals, such as garnet and micas, which are developed in a limited contact zone. Mechanical metamorphism evinces itself in the development of shear zones and of foliation as the granite mass is approached.

During the Mesozoic times and after the injection of the granite large extrusions of volcanic rocks took place. These, as well as the granite, were subsequently somewhat deformed. This deformation was more intense along the axis of the Coast range, where the granites were in part changed to gneisses and mica-schists. Subsequently another intrusion of igneous rocks took place, which, though widely distributed, was not great in bulk. This epoch of injection is represented by the large number of dikes, usually quite massive, which are found in different parts of the region. Deformational movements since Kenai times have been only of minor importance, as is shown by the very gentle folding found in the Tertiary beds. So far as known, there is absolutely no evidence of a southern extension of the post-Tertiary disturbance which Russell* noted in Saint Elias regions. The most recent evidences of dynamic activity are the volcanic rocks of mount Edgecumbe and some basalt flows which have been found in various parts of the province.

One of the effects of the crustal movements is to produce lines of weakness in the rocks which have been sought out by the erosive agencies. These structural lines, which are shear zones and lines of foliation, have affected not only the bedded but also the massive rocks, and consist of two systems, the one having nearly a north and south trend, the other running northwest and southeast. The position of the channels and inlets of this coastal belt is largely determined by these structural lines (compare map, page 257).

CORRELATION

The stratigraphy of the regions lying adjacent to the province under discussion is too imperfectly known to enable correlations to be made. It will be of interest, however, to draw attention to certain analogies of stratigraphic succession and lithologic character in adjacent regions. This is especially true of the field to the south, where the Canadians have done some more or less detailed mapping.

In a previous report † the writer grouped the Carboniferous and Devonian beds of the upper White and Tanana rivers together under the name Nutzotin series. This Nutzotin series would in a measure correspond to the subdivision called Upper Paleozoic on the accompanying map, but will probably also embrace a part, at least, of the argillites which lie adjacent to the Coast range. In the report cited the limestones of Glacier bay were all put in the Nutzotin series, as they were then believed to be Carboniferous. In the same report the pre-Devonian sediments are grouped together as the Kotlo series, which would include the rocks of the Lower Paleozoic, as defined in this report. As in southeastern Alaska, the two series are separated by an unconformity, and there are, broadly speaking, certain lithologic similarities.

In the Copper River district Schrader ‡ and Spencer have described two formations which probably fall in the Upper Paleozoic. These are the Chitistone limestones, believed to be Carboniferous, and the underlying Nicolai greenstone. This limestone can be provisionally correlated with the Upper Paleozoic beds of southeastern Alaska. The subdivision made by Schrader and Spencer of the beds below this limestone finds but little analogy in the older sediments of the region under discussion.

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*Nat. Geog. Mag., vol. iii, 1891-'92, p. 167.

†A reconnaissance from Pyramid Harbor to Eagle City. Twenty-first Ann. Rept. U. S. Geol Survey, part ii, p. 359.

‡Geology and mineral resources of the Copper River district. U. S. Geol. Survey, 1901.

The comparison of the Mesozoic beds of the two regions does not suggest correlations. In the southern region the Mesozoic is represented, as far as known, more especially by conglomerates and coarse fragmental beds, while in the Copper River basin the rocks of this age are chiefly limestones and black slates. The Kennicott series, however, in the Copper river of Jura-Cretaceous age is made up of fragmental rocks similar in character to the Mesozoic of southeastern Alaska. The Tertiary sediments of southeastern Alaska are chiefly Kenai, and this horizon has been identified in many parts of Alaska.

Dawson's last investigation * on the geology of this northern region is a report on the Kamaloop district in southern British Columbia.

This work was done in much more detail than any which preceded, and the stratigraphic succession was definitely determined.† The Kamaloop region is too distant from the province under discussion to make correlations possible. It is interesting to note that the Cambrian period is represented by beds aggregating a thickness of 40,000 feet. It seems probable that some of the Lower Paleozoic beds of southeastern Alaska may eventually be found to be of Cambrian age. The absence of Silurian and Devonian in the Kamaloop region is noteworthy in comparison with the southeastern Alaskan section. Dawson finds definite evidence of the existence of pre-Cambrian rocks in this southern district.

In Queen Charlotte islands ‡ Dawson grouped the Triassic and Carboniferous beds together, and states that these are unconformably overlaid by Cretaceous rocks. After the deposition of Triassic, folding took place, and it was probably during this period that the granites were intruded. From the descriptions of Dawson these Triassic and Carboniferous rocks show a striking analogy to the metamorphic argillites which lie adjacent to the Coast Range granites in southeastern Alaska. Dawson finds a large amount of volcanic material in the southern part of Vancouver island, which he believes to be Carboniferous. These volcanic effusives seem to have the same stratigraphic position as some found in southeastern Alaska which have been provisionally assigned to the Mesozoic.

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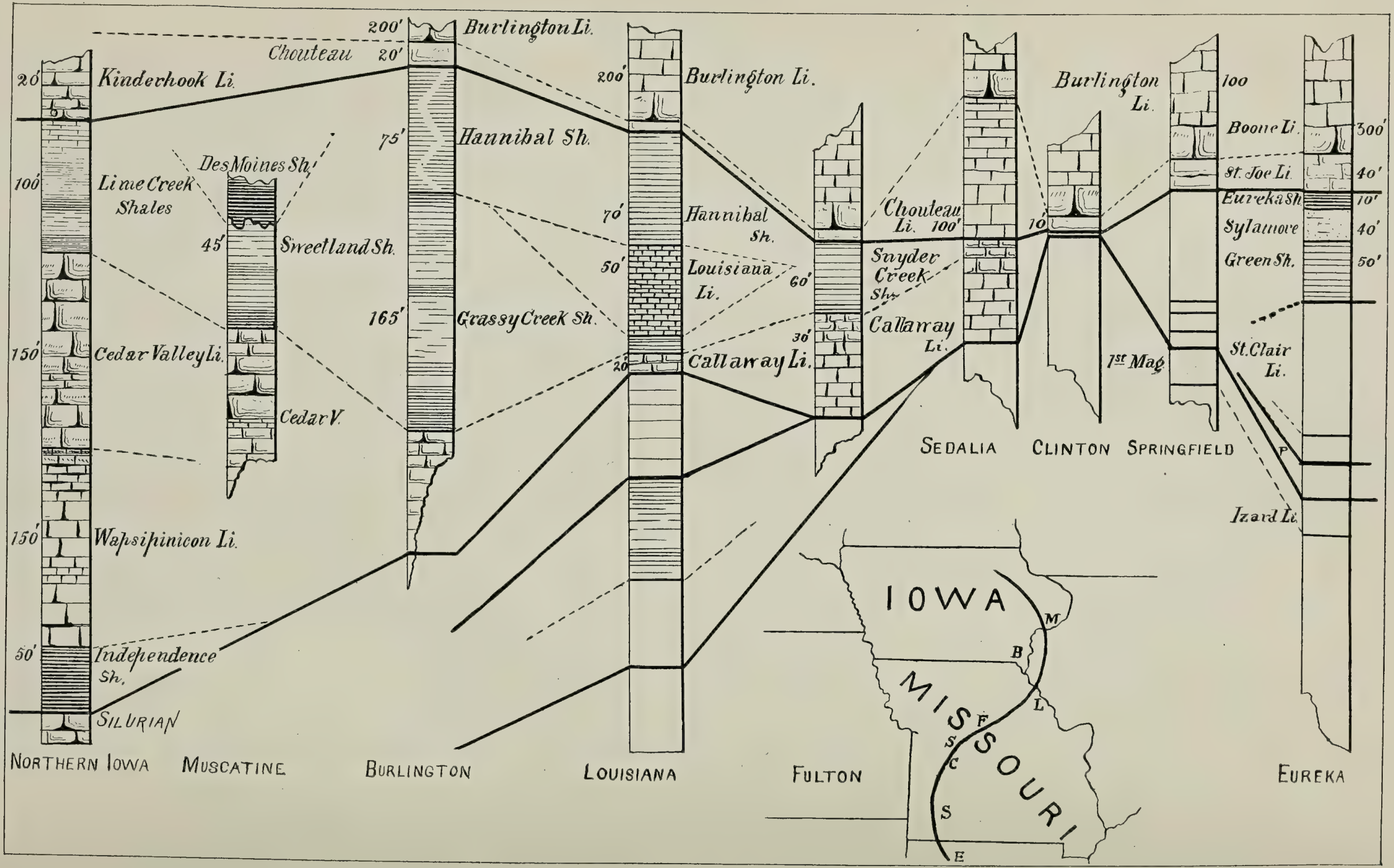
* George M. Dawson: Report on the Area of the Kamaloops, map sheet, British Columbia. Geol Survey of Canada, Ann. Rept., new series, vol. vii, 1894.

* Dawson summarized the results of his twenty-five years of investigation of northwestern America in a presidential address to the Geological Society of America. "Geological record of the Rocky Mountain region in Canada." Bull. Geol. Soc. Am., vol. xii, 1900, pp. 57–92.

‡ George M. Dawson: Report on the Queen Charlotte islands. Geol. Survey of Canada, 1880, p. 45 B.

The Mesozoic beds in the province under discussion would seem to correspond to the Cretaceous of the Queen Charlotte islands, both in stratigraphical position and lithologic character. Dawson notes a period of folding which succeeded to the deposition of the Cretaceous. The Tertiary rocks described by him are chiefly volcanic, and are provisionally assigned to the Miocene.

On the lower Skeena river and in the vicinity of Port Simpson, Dawson found a metamorphic series, made up of mica-schists and some limestones, closely associated with gneisses. These would seem to be the southern extension of the Ketchikan series, part of the belt of argillites which lie adjacent to the granite of the Coast range.


200'
Burlington Li.
Chouteau
20'
20'
Kinderhook Li.
75'
Hannibal Sh.
200'
Burlington Li.
Burlington Li.
100
Boone Li.
300'
St. Joe Li.
40'
Eureka Sh.
10'
Sylamore
40'
Green Sh.
50'
Des Moines Sh.
100'
Lime Creek Shales
45'
Sweetland Sh.
70'
Hannibal Sh.
Chouteau Li. 100'
10'
50'
Louisiana Li.
60'
Snyder Creek Sh.
165'
Grassy Creek Sh.
30'
Callaway Li.
150'
Cedar Valley Li.
20'
Callaway Li.
1st Mag.
St. Clair Li.
Cedar V.
P
Izard Li.
150'
Wapsipinicon Li.
50'
Independence Sh.
Silurian
Sedalia
Clinton
Springfield
IOWA
MISSOURI
M
B
L
F
S
C
S
E
Northern Iowa
Muscatine
Burlington
Louisiana
Fulton
Eureka

DEVONIAN SECTION OF THE MISSISSIPPI VALLEY

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VOL. 13, PP. 267-292, PL. 44 AUGUST 6, 1902

DEVONIAN INTERVAL IN MISSOURI

BY CHARLES R. KEYES

(Presented before the Society January 2, 1902)

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Introductory

In central Missouri Carboniferous stratigraphy presents unusual relationships. Nowhere else in the whole region does the same succession of Paleozoic terranes prevail. Beginning with the typical Chouteau limestone as the basal member, the Carboniferous sequence rests directly on Ordovician dolomites. In other parts of the state the hiatus is represented by extensive sections of Silurian and Devonian age. Of these the last mentioned is by far the most important. In the region contiguous the deposits laid down during the Devonian interval are in many respects of exceptional interest.

It is here purposed to regard the beds formed during the Devonian interval as a formation having distinct individuality. While unequally developed, it is not so indefinitely defined as has appeared at first glance or as has been generally supposed. The ascribed vagueness has been found to be due in great measure to the fact of its being little understood.

In the neighboring areas of uninterrupted sedimentation the sequence comprises all those strata lying between the limestones about which there has been but little doubt as to their Silurian age and the undoubted Carboniferous limestones. The beds of this as yet not fully differentiated terrane are commonly known as the "Niagara" dolomites. Above the sequence is the great Mississippian series.

The succession of beds thus stratigraphically delimited is believed to be wholly representative of Devonian deposition. In the following pages the reasons for this opinion are set forth. The conclusions arrived at, while not novel, have never before been published. Exact information, recently acquired, has so strongly confirmed the main suggestions that some of the data on which they are based appear worthy of special note at this time.

The data relative to the northern part of the region were collected partly under the auspices of the Iowa Geological Survey. The information concerning the more southern district was secured mainly during the prosecution of the work of the Missouri Geological Survey. Visits were also made into the extreme southern portion of the region under consideration and eastward into Illinois.

It has no doubt often appeared strange that in the central Mississippi valley, where the Silurian terranes are so well developed over such vast areas and where the basal limestones of the Carboniferous are so sharply cut off from the formations below, that our knowledge of the sediments occupying the space between the two great systems should so long remain in such an unsatisfactory condition. However, as will appear, there are very good reasons for the lack of exact information concerning the Devonian of the region.

DEVONIAN PROBLEMS PRESENTED

Irrespective of the actual geological age of the several parts of the interval deposits represented in the Mississippi valley, there arise a number of questions which must find answer before the stratigraphy of the region can be considered as even approximately understood. The statement of some of these propositions may be given here. In the present connection many others which have been formulated are passed over.

The main proposition is whether or not the deposits lying between the "Niagara" and the Mississippian series are all to be regarded as belonging to the same geological system.

A second important problem has to do with the harmonizing of the northern sections, where more than 500 feet of Devonian strata are represented, with the central sections, where little or no sediments exist between the Silurian and the Mississippian, and with the southern sections, where, as in Arkansas, for example, the Interval beds have a thickness of 100 feet or more.

In the so-called transition beds lying immediately beneath the Burlington limestone another group of problems is presented. Of first importance is the query whether there are here any beds which can be advantageously denominated Devono-Carboniferous.

Not of least significance is the real taxonomic value of the original Kinderhook, the classificatory reference of its several members, and its stratigraphical equivalency in other localities.

A fifth great problem deals with the unconformities as indicative of important changes influencing sedimentation.

GENERAL GEOLOGICAL CROSS-SECTION OF THE REGION

MAIN FEATURES

The direction of the general cross-section is indicated on the small sketch map accompanying the drawing (plate 44). A supplementary section may be considered as extending around the eastern end of the Ozark uplift.

The most notable feature is the great shale bed at the top of the sequence. This thickens enormously in northern Missouri, where, in its middle, it completely envelops the great calcareous lense known as the Louisiana limestone. The most typical formations of the Upper Devonian, which are so thick in the north, successively thin out southward, until in central Missouri even the main member, the great Cedar Valley limestone, fails altogether.

The shales in Arkansas preserve only the characters of the upper shale member of the north. There is nothing in this part of the cross-section to represent the limestone members in the more northern sections.

Around the eastern flank of the Ozarks the Devonian is greatly diminished in thickness, yet it nevertheless retains its characteristic limestone as its major member and is abundantly fossiliferous.

BASE OF THE CARBONIFEROUS

The base of the Carboniferous is in this connection assumed to be the bottom of the Chouteau limestone wherever this is present, and when not present, the Burlington limestone or lower member of the Augusta terrane of the Mississippian series. The reasons for considering this horizon at the base of the Chouteau terrane as the plane separating the two great systems of strata are given elsewhere. Whatever may be the real age of the various Interval beds, the horizon here regarded as the base of the Carboniferous is remarkably persistent over a vast area, and, moreover, in sections is everywhere easily recognized.

Without regard to any possible change in the future in its taxonomic position, the base of the Chouteau must always be considered as an important stratigraphic guide-horizon. Throughout the western Interior basin, from the point where it rises out of the ground in northern Iowa and is cut by recent peneplanation of the region south through Missouri and into Arkansas, there is no difficulty is locating this stratigraphic level. It is a feature in the stratigraphy that is conspicuous, ever present, never mistaken. Far to the southwest it appears to retain all its distinctive features unimpaired.

SUPERIOR LIMIT OF THE SILURIAN

Throughout the Mississippi valley little hesitancy has been evinced in delimiting the Silurian beds. Whether in the consideration of its lithologic features or of its faunal characteristics, the separation from overlying formations is everywhere on sharply drawn lines. This guide-horizon in the general correlation of the strata is easily recognizable even in deep-well sections. Whatever may be the geological age of beds above that may appear obscurely defined or devoid of readily determinable features, one may always feel assured that the deposits will never prove to belong to the Silurian.

In the upper Mississippi basin, as far south as the Missouri river, these Silurian beds are almost invariably denominated "Niagara dolomites." While, of course, this formation can not be regarded as coextensive with the similarly named formation of the Silurian of the New York section, and can not be considered as having any legitimate claim to the title which it usually bears, less confusion is likely to arise by continuing for the present the old name than by introducing a more appropriate but new term.

The important point to be taken into consideration in the present connection is the fact that the "Niagara" dolomite when met with is a terrane about which there is never any doubt as to stratigraphical location. It is a datum plane from which all higher geological sections may be at once referred.

LOWER PALEOZOIC FORMATIONS

Of similar importance in the correlation of the Interval deposits are the Ordovician strata of the region. Such formations as the "Hudson" shales and the "Trenton" limestone, for examples, are well developed over broad areas. These terranes everywhere afford good checks in paralleling vertical sections in localities more or less widely separated from one another.

THICKNESS OF THE INTERVAL DEPOSITS

The space between the basal plain of the Carboniferous and the top of the Silurian is not great when compared with the great thicknesses of strata in other regions. In northern Iowa, where the maximum measurement is greatest, the distance separating the two levels is about 450 feet. To the southward this figure gradually grows less and less until in north Missouri it is not more than 150 feet, including the thickness of the Hannibal shales and the Louisiana limestone. Around the western flank of the Ozark dome this value is reduced to zero, but in northern Arkansas it again expands to nearly 100 feet.

On the eastern side of the Ozark uplift the Interval deposits are at no point reduced below about 75 feet.

FORMATIONS REPRESENTED BY THE INTERVAL

IOWA TERRANES

The formations referred to the Devonian have received of late years a number of new designations. The general section, however, may be given as follows:

General Devonian Section of Iowa

	Feet
Lime Creek shales	100
Cedar Valley limestone	150
Wapsipinicon limestone	150
Independence shales	50

From northeastern Iowa southward the main member of the Devonian—the Cedar Valley limestone—maintains its full development and characteristics to the southeastern part of the state. It is an easily recognizable stratum in deep-well sections to beyond the state boundaries.

The basal member, called the Independence shales by Calvin,* is comparatively limited in its geographic extent.

The uppermost shale member appears to have a rather remarkable distribution and development. Should recent correlations be correct, one problem will have been solved that has completely baffled investigators from the earliest inquiries in this region, more than 50 years ago.

The Sweetland beds of Muscatine county † appear to be the stratigraphical equivalents of the Lime Creek shales. They are also to all appearances the basal part of the so-called Kinderhook shales at Burlington, but their stratigraphic level is probably 100 feet beneath low water at that place, 60 feet only of the shale formation being above the river.

The nominal history of these beds is full of interest. From the time when Hall ‡ first brought these beds into notice the conclusions drawn by this author seem to have been misunderstood. To this point attention will be directed later.

NORTH MISSOURI BEDS

Between the Silurian limestones and the Burlington limestone there is, in northern Missouri, a succession of beds the geological age of which has long been a subject of controversy. The section § here referred to the Interval may be thus expressed :

General North Missouri Succession

	Feet
Hannibal shales	75
Louisiana limestone	50
Grassy Creek shales	30
Callaway limestone	30

Of the terranes mentioned, the Callaway limestone is believed to be the southern extension of the great Cedar Valley limestone of Iowa. While rich in fossils, its fauna has never been described. Only a few species have been noted as coming from it, and these have never been figured.

The Louisiana limestone has been clearly shown || to be a rather lim-

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* Bull. U. S. Geol. and Geog. Survey Terr., vol. iv, 1878, p. 725.

† Iowa Geol. Survey, vol. ix, 1899, p. 289.

‡ Geology of Iowa, vol. i, 1858, p. 88.

§ Proc. Iowa Acad. Sci., vol. v, 1898, p. 59.

|| Journal of Geology, vol. viii, 1900, p. 317.

ited lense included in a huge shale formation. The upper part of this shale is called in Missouri the Hannibal terrane, and the lower part the Grassy Creek formation. At Burlington the two shale beds, which farther south are so distinct and separated by a great limestone, form a single unbroken shale sequence. The faunas contained in the several component formations are fully discussed farther on.

HIATUS OF WEST-CENTRAL MISSOURI

On the west flank of the Ozarks, Devonian deposition appears to be entirely wanting. Near Sedalia the beds are very thin. Farther south, near Clinton, the sections show the Carboniferous limestones resting directly on the Ordovician, as has been so well demonstrated by Marbut.* The explanation of this fact has not yet been determined satisfactorily. There have been difficulties in the way of direct observation in those districts in which inquiries have been carried on, and opportunity has not been given to conduct the search in neighboring localities.

DEVONO-CARBONIFEROUS IN SOUTHWEST MISSOURI

The manifest tendency of late years to throw together the Devonian and Carboniferous beds of southwest Missouri merely because there have existed slight differences of opinion among various observers as to the geological age of some of the unimportant layers does not appear to be conducive of the results hoped for. The attempts to make up for insufficient observation by merging formations really distinct under a single name not only does not solve the various problems presented, but merely defers and makes harder the solutions. What is really needed is clear differentiation, clear delimitation, and clear definition of the several terranes.

As given by Shepard,† the general section of the Interval representatives in southwestern Missouri is as follows :

Southwest Missouri Section

	Feet
Hannibal shales	90
Louisiana limestone	10
Phelps sandstone	15
Sac limestone	15
King limestone	15
Eureka shale	10

The typical Chouteau limestone appears to be well represented above the so-called Hannibal shales, and has a thickness of often 30 feet. The shale bed which has been called the Hannibal may or may not be the stratigraphic extension of the typical Hannibal of the northeast part of the state, but it probably is. For the present it may be best to adopt Weller's name, Northview shale, for this formation in southwest Missouri.* The so-called Louisiana limestone of southwest Missouri is certainly not a part of the Louisiana limestone of the typical locality. The "Louisiana" limestone, the Phelps sandstone, the Sac limestone, and the King limestone, of Greene county, will doubtless be found to be parts of one terrane, as Weller † has suggested. While it is no doubt true that the faunal evidence of Shepard's differentiation and classification of these beds is very slender, it is also true that for reasons elsewhere stated the criticism of this author's correlations by means of the fossils rests on foundations almost as uncertain.

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* Missouri Geol. Survey, vol. xii, 1898, part ii, p. 121.

† Missouri Geol. Survey, vol. xii, 1898, p. 49.

The so called Eureka shale and all of the section given, up to the base of the Burlington limestone, Weller places in the Kinderhook.

ARKANSAS SECTION

According to Professor Williams's recently published account of the succession of faunas in northern Arkansas,‡ the following grouping of strata between the Ordovician and the Boone chert (Burlington limestone) is presented:

Northern Arkansas Succession

	Feet
Saint Joe marble	50
Eureka shale (typical)	30
Sylamore sandstone	40
Eureka shale (in part) and green shales	50
Saint Clair limestone (Niagara)	155

The Saint Joe limestone is regarded by the author mentioned as equivalent to part of the Burlington limestone of the more northern sections. The evidence gathered from the Missouri investigations indicates rather that it represents the Chouteau. He considers the typical Eureka shale as forming the base of the Carboniferous. The Sylamore sandstone and the shales immediately associated underneath are placed in the Devonian.

NATURE OF KINDERHOOK FORMATION AND CHOUTEAU FAUNA

GENERAL STATEMENT

On account of its lying on the border zone of the Devonian and the Carboniferous, the Kinderhook formation has a special interest in the consideration of the internal deposits. There has, in the last half century, been so much controversy in regard to the age and distribution of the Kinderhook that we must now look into original meanings before attempting to arrive at our final conclusions.

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* Trans. St. Louis Acad. Sci., vol. ix, 1900, p. 9.

† Journal Geology, vol. ix, 1901, p. 134.

‡ Arkansas Geol. Survey, Ann. Rep., 1892, vol. v, 1900, p. 277.

Three separate and distinct lines of consideration at the outset arise. They have to do, first, with the stratigraphy; second, with the faunal features, and, third, with the geological age according to the most approved methods of determination. Each of these phases has its own individuality and requires a perfect independence of treatment. Usually no distinction is made, and therein is the main source of much of the confusion that has arisen in regard to the nature and relations of the Kinderhook.

OWEN'S SECTION

As one, after being in the field, passes in review the published data relating to the beds which have given rise to the Kinderhook controversy, he can not help looking on many of the points of dispute in a very different light from that in which they were originally presented. Standing now, after an elapse of 60 years, one can not but marvel at the wonderful discernment displayed in the first efforts to differentiate the Carboniferous formations of the Mississippi valley. Time has not dimmed the work of that pioneer in American geology, David Dale Owen, in his discriminations of the Carboniferous limestones of the continental interior.*

Owen's arrangement of the geological formations of the region rests primarily on lithologic grounds; but fossils received full consideration. So far as it goes, this writer's scheme is essentially the plan now accepted. New titles have displaced the old, but the division lines remain almost unaltered.

To the shales underlying the Encrinital (Burlington) limestone at the city of Burlington and the city of Hannibal, Owen gave the name "Argillo-calcareous group." Although the nether limit was not specifically located, the group is practically coextensive with what was later termed the Hannibal shales.

HALL'S DETERMINATIONS

Fresh from the rich paleontologic fields of New York, where a standard Paleozoic section for America had then been but recently established, James Hall was easily led to discover in the rocks of the Mississippi valley the faunal horizons which he knew so well in his own state. In the Argillo-calcareous group of Burlington and Hannibal he fancied that he recognized the Chemung of the east.* He had already traced the Devonian formations westward from New York to the Mississippi river.

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*Geol. Survey Wisconsin, Iowa, and Minnesota, 1852, p. 90.

The determination of the Devonian age of the shales at the base of the section at Burlington and at Hannibal did not rest on observations at these points alone. There was a correlation of these beds with lithologically similar beds farther to the northward, at Muscatine and in northern Iowa, where there was obvious association with undoubted Devonian limestones. Singularly enough, after 40 years of discussion, Hall's correlation and assignment of Devonian age to the strata are again beginning to be demonstrated to be correct. At no time in all this prolix controversy did Hall himself abandon his early views regarding the Devonian age of these shales which have until lately been generally called the median member of the Kinderhook.

SWALLOW'S VIEWS

With the aid of Meek and Shumard, the first state geologist of Missouri recognized in his state, immediately beneath the great Encrinital limestone, a three-fold terrane which he referred to the Chemung division of the Devonian.†

Swallow introduced a new member into the succession as reported from the Mississippi river, calling it the Chouteau limestone. In central Missouri this limestone attains a maximum thickness of more than 100 feet. No one would suspect from examinations along the Mississippi river that such an important formation existed at the base of the Burlington limestone; hence it is not very strange that the geologists who had only seen the river sections gave the dozen feet of earthy limestone at the bottom of the Burlington so little consideration.

Meek found the Chouteau limestone in the original locality to contain many Carboniferous types of fossils. Their great resemblance to those in the limestones above had from the first a tendency to shake his faith in the Devonian age of the so-called Chemung beds.‡ In his later report,§ on Saline county, the next year (though not published until seven years later) he is fully convinced that the Chouteau limestone should be associated with the Carboniferous rather than with the Devonian. It is a noteworthy fact in this connection that in central Missouri the lower two members of Swallow's Chemung appear to be wanting.

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*Geology of Iowa, vol. i, 1858, p. 88.

Trans. Assoc. American Geol. and Nat., 1843, p. 267.

†Missouri Geol. Survey, 1st and 2d Ann. Repts., 1855, pt. i, p. 103.

‡Missouri Geol. Survey, 1st and 2d Ann. Repts., 1855, pt. ii, p. 103.

§*Ibid.*, 1855–'71, 1873, p. 160.

MEEK AND WORTHEN'S KINDERHOOK FORMATION

The proposal of the term Kinderhook as a geological title was unfortunately made amidst personal animosities. When, in 1860, Worthen and Meek began their labors on the geological survey of Illinois, both had become very bitter against Hall, and could not restrain themselves from making attempts to overthrow some of the latter's work. Worthen had fancied an unpardonable grievance because, while connected with the Iowa geological survey under Hall, the latter had verified some of the former's observations on his own account, and instead of adopting the names of formations which had previously been suggested in manuscript had used titles of his own. Meek had just retired from Hall's laboratory in Albany as a result of a quarrel, in which he was greatly at fault, about the proper draughting of some fossils for the latter's New York report. Intense rivalry had also now arisen between Hall and Meek and Worthen as to who should first describe all the new fossils which were about this time being discovered in the rich fields along the Mississippi river in Illinois and the adjoining states.

Thus, in considering the beginnings of the Kinderhook controversy, there is a large element of biased judgment that has to be eliminated. Many misstatements of fact, misquotations of contemporaneous opinion, and misinterpretation of published work appeared in the first paper by Meek and Worthen on the Kinderhook.* No doubt the intentions of the Illinois authors were to present the facts exactly as they existed; but, with glasses somewhat colored, enthusiasm born of new discovery, and jealous rivalry, they evidenced a haste that was not customary with these usually very careful workers.

But, aside from the shortcomings mentioned, there appears to be a far more important factor overlooked in the proposal of the group Kinderhook and in assigning it all to the Carboniferous. Meek and Worthen's conclusions were far too sweeping. The triple-membered Chemung of Swallow had not all been examined by the authors named. To them practically only the upper member had yielded fossils. The Vermicular (Hannibal) shales and Lithographic (Louisiana) limestone were admittedly barren of organic remains, except perhaps half a dozen species and almost as few individuals, which had been accidentally secured from the layers at the very base of the last mentioned formation.

Meek had already studied in Missouri only the fossils from the typical Chouteau limestone, and had come to regard them as Carboniferous forms. Meek and Worthen's Illinois collections are now known to have all been made from layers within a few feet of the bottom of the Burlington limestone.

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* Am. Jour. Sci. (2), vol. xxxii, 1861, p. 167.

The fauna of Meek and Worthen's Kinderhook group is therefore not the fauna of the whole of the three-fold terrane which has long been known to geologists as the Kinderhook, but it is the fauna of only the upper limestone member, the Chouteau limestone. By them the fossils of the lower two members of their Kinderhook were not taken into consideration to the least extent. To them the lower faunas were practically unknown. In fact, they delimited a formation stratigraphically. For the whole they defined faunally only a very small part of this formation. They assigned a definite geological age to the whole when they were actually justified in ascribing an age to a single member. The Kinderhook fauna, as we have long known it, is in reality only the fauna of the Chouteau limestone. We know now that other and very different faunas occur in the shales and limestones immediately underneath the Chouteau limestone.

CHOUTEAU STAGE

The biological geologists are inclined to apply the term Chouteau to the earliest of the three faunal categories into which they subdivide the Eo-Carboniferous of the Mississippi valley. The title thus refers to the Kinderhook terrane of Meek and Worthen. Before the application of the term in this sense the name had already been formally given to the upper member of the Kinderhook.* Broadhead's subsequent extension† of the title making it synonymous with Kinderhook does not establish its validity.

Chouteau, if it is to be retained as a faunal term in geology, can only be made to apply to the stage represented by the original Chouteau limestone. In this sense it satisfies all the requirements of dual classification in geology. Moreover, it may refer to a fauna that is a compact unit. It eliminates, as will hereafter be shown, the elements which are not Carboniferous in character.

Referring to terranes, the name would apply to the lowermost member of the Mississippian series.

The fauna which is generally thought to be the fauna from the original Chouteau limestone is at best a fanciful medley of shadowy definition. Practically no detailed work has yet been done that is published. Careful determination of the exact horizons of the various forms has not even been attempted. Of the species described from the original

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* Missouri Geol. Survey, 1st and 2d Ann. Repts., 1855, p. 103.

† Ibid., Rept. 1873–'74, 1874, p. 20.

Chouteau in central Missouri, many are now known to be from formations other than the terrane under consideration. It is small wonder, therefore, that the Chouteau or Kinderhook fauna as we have long known it is apparently ill defined, anomalous, and puzzling. In the critical study of the lowest Carboniferous faunas of the Mississippi valley there is need, before all else, of exact determinations of the various organic forms from the original Chouteau limestone of central Missouri. It is only with this type fauna that the faunas of the Kinderhook of other localities and other horizons can be with profit compared. Until the fossils from the original Chouteau limestone are carefully collected and studied anew in their entirety, the "Chouteau fauna" must be regarded as a quantity unknown.

Faunal Relations of the Interval Deposits

DEVONIAN FAUNAS OF THE NORTH

With a single exception, so far as known, the Devonian age of the formations already enumerated in the Iowa section and ending above with the Lime Creek shales has never been questioned. In considering a remarkable fauna at the base of the Chemung, at High Point, New York, Williams * was led to make some comparisons similar to those made sometime earlier by J. M. Clarke † of this fauna with the Lime Creek fauna, in which the latter was considered as having features which were strikingly Carboniferous in aspect. However, after Calvin's demonstration ‡ that the Lime Creek fauna was typically Devonian for the region, the first-named author was induced to change the views § which he had previously expressed. There is practically no question now but that the Lime Creek beds belong to the Upper Devonian.

Where the Lime Creek beds are typically developed in Floyd and Cerro Gordo counties, in northern Iowa, Calvin ‖ has shown recently that they are overlain by shaly magnesian limestone carrying Kinderhook fossils—that is, Chouteau forms. This limestone is very similar to the "Kinderhook" limestone at Le Grand, Iowa, which is believed to be stratigraphically continuous with the Chouteau limestone of central Missouri.

CHEMUNG FORMATION IN EASTERN IOWA

The beds in eastern Iowa which were early referred by Hall ¶ to the same geological age as the Chemung, of the New York section, consist chiefly of greenish and bluish shales and yellowish sandstones. They are now called the Lime Creek shales in northern Iowa, the Sweetland shales in Muscatine county, in eastern Iowa, and the Kinderhook shales or Hannibal shales at Burlington and in northeastern Missouri. All available information now indicates, without much room for doubt, that the beds of the several localities are stratigraphically one and the same formation, but that at Burlington it is only the upper part of a great shale terrane that is exposed to view, while on Lime and Sweetland creeks it is the lower part that has been open to inspection.

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*Am. Jour. Sci. (3), vol. xxv, 1883, p. 97.

† U. S. Geol. Survey, Bull. 16, 1885.

‡ Ibid., p. 432.

§ American Geologist, vol. iii, 1889, p. 230.

‖ Iowa Geol. Survey, vol. vii, 1897, p. 144.

¶ Geology of Iowa, vol. i, 1858, p. 88.

Assuming that this be true, some of the causes for the protracted controversy which has arisen regarding the age of the beds in question may be inquired into. First to present itself is the fact that the Chemung, or Kinderhook of Meek and Worthen, or Chouteau group of Broadhead (not of Swallow), has been invariably considered as a homogeneous geological unit. When the term Kinderhook was first proposed and stated to be Carboniferous in age it was, as just stated, made to cover everything in the region which had been previously called Chemung. No attempt was made to inquire into the matter of whether or not some part of the newly named formation might not actually possess a different geological age. It is known now that in the case of the original locality the lower four-fifths of the Kinderhook was not critically considered, but dumped bodily into the supposed new receptacle. The Spirifer capax beds of Muscatine, which were called Chemung by Hall, were likewise, without examination, placed by Miller* in the Carboniferous. When Calvin † came to inquire into the Muscatine problems he found a strange state of confusion.

When I first personally visited the Muscatine localities, it was as a college student, before I even knew that there was such a thing as a Kinderhook controversy. I was quite familiar with the Devonian fossils of districts farther north, but I was perfectly unbiased in approaching the problems relating to the geological age of the various horizons in the locality under consideration. The Spirifer capax beds were determined not to be Carboniferous yellow sandstones at all, but yellow, finely crystalline dolomites carrying the same fossils as some of the Cedar Valley limestones near by and farther to the northward.

Hall certainly did make the mistake of placing the Spirifer capax beds above the green "Chemung" (Sweetland) shales, for it is now demonstrated that their position is below the latter; but it is readily understood after visiting the localities how such a transposition of horizons in the section could be made. At the time of Hall's rapid reconnaissance, railroad and highway cuttings were unknown, and the opportunities for making exact observations were not so good as they became a generation later. The green Sweetland shales are even now exposed only at a few points, for they lie in this locality at a level where they were subjected to profound subaerial erosion, which took place just prior to the deposition of the Coal Measures. The Sweetland shales are perhaps 40 feet thick at the point of their greatest development in this locality. They are absent in many sections where carboniferous erosion entirely removed them, and even penetrated the Cedar Valley limestone. The horizon of the Spirifer capax beds is only a few feet beneath the bottom of the Sweetland formation. Above the latter is a yellow sandstone in the basal part of the Coal Measures. In color, in texture, in general appearance, and in manner of weathering, this sandstone is almost identical with the dolomite carrying *Spirifer capax*. Strange as the statement may appear, it is only after the closest inspection that the two rocks can be distinguished from each other. On the opposite side of the Mississippi river, at the mouth of Stonecoal creek, the two formations lie in conjunction.

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*American Paleo. Foss., 1887, p. 129.

† American Geologist, vol. iii, 1889, p. 25.

Unless one is able to examine the several lines of juncture between the different beds in the section, he would hesitate but little in inferring that the casts of *Spirifer capax* were really from some part of the sandstone above the shales. Hall's mistake was a very natural one. His hasty parallelism of the Muscatine section with that of Burlington has also many points to sustain it, and after all he does not seem to be so far in the wrong as subsequent writers would have us believe. The most recent information goes to show that in his general assertions he came surprisingly close to the truth. If later investigations have not been erroneous, his correlation of the Sweetland beds, as we now call them, with the green shales at Burlington is essentially correct. There is this difference: The horizon of the Sweetland shales probably comes somewhat lower down than the level of the river at Burlington—somewhere in the 150 feet that the shales at the latter place are known to extend below the base of the exposed section.

Regarding the Devonian age of the Spirifer capax beds of Muscatine Calvin* has given a full account. Still later, Udden† published many additional details in connection with his report on the geological survey of Muscatine county. Worthen and Shaw‡ were the first, though only incidentally, to call attention to the fact that the Spirifer capax beds were dolomitic.

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*American Geologist, vol. iii, 1889, p. 25.
†Iowa Geol. Survey, vol. ix, 1899, p. 289.
‡Illinois Geol. Survey, vol. v, 1873, p. 223.

The relations of the Burlington section and the section of the typical Kinderhook (Chemung of the early Missouri geologist) have recently been clearly set forth.[*] It has been shown that the basal shales of the Burlington section represent much more than the Hannibal shales or median member of the original Kinderhook section. The 150 feet of shales beneath the waterlevel very nearly correspond to the Grassy Creek shales of Missouri, a formation nearly 200 feet in thickness, lying immediately below the Louisiana limestone and base of the Kinderhook. Northward, as has been stated, the Louisiana limestone, which is 50 feet thick at the type locality, becomes thinner and thinner and finally fails altogether soon after passing the southern Iowa boundary. This brings together at Burlington the Grassy Creek shales[†] and the Hannibal shales, thus forming a single great stratigraphic and lithologic sequence.

The Grassy Creek shales, so far as their faunas are concerned, are undoubtedly Devonian in age. The rich faunas recently found in the so-called Kinderhook shales that are above the waterlevel at Burlington present strong Devonian affinities.[‡] This would indicate rather clearly that faunally the shale section at Burlington is a unit also. Lately Weller,[§] who is giving special attention to the Kinderhook faunas, has attempted, entirely on faunal grounds, to locate at Burlington the horizon of the base of the Louisiana limestone at the bottom of the fine argillaceous limestone above the Chonopectus sandstone, a level which is only 30 feet below the bottom of the Burlington limestone and at the top of the green shales of this section.

DUAL NATURE OF ORIGINAL KINDERHOOK FAUNA

Ten years ago the writer visited along the Mississippi river all the type localities of the formations belonging to the Lower Carboniferous, or Mississippian series. It was for the express purpose of obtaining at first hand definite data relating to exactly what was referred to in the literature of the subject. Without attempt to revise the classification of the series from the foundation up, a summary of that investigation was published[||] under the title of the "Principal Mississippian Section."

Among many other things, it was found at that time that the actual faunal characteristics of the original Kinderhook formation were very different from the ideas which had been gathered from a perusal of the literature. The ascribed fauna of the lowermost member of the four-fold Mississippian series was in fact a fancied fauna instead of a real one extending through the whole section of the Louisiana, Hannibal, and Chouteau divisions. Moreover, the ascribed fauna was also found to be a limited fauna of only the upper part of the Kinderhook. With a few exceptions, the forms described as coming from the Kinderhook had been collected from only the uppermost layers of that formation—the Chouteau limestone and its stratigraphical equivalents. Practically no extended examinations of the fossils from the Hannibal shales and the Louisiana limestone had ever been undertaken by the earlier geologists. Generally, these two formations had been reported as barren of organic remains. A few species had, however, been noted from the very base of the Louisiana limestone, but no indication of the real horizon had been given in the descriptions.

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[*] Journal of Geology, vol. viii, 1900, p. 315.

[†] Proc. Iowa Acad. Sci., vol v, 1898, p. 68.

[‡] Proc. Iowa Acad. Sci., vol. iv, 1897, p. 39.

[§] Trans. St. Louis Acad. Sci., vol. x, 1900, p. 123.

[||] Bull. Geol. Soc. Am., vol. iii, 1892, p. 283.

The surprise in store was that both at Burlington and at the original locality (the cities of Louisiana and Hannibal are only a few miles from the village of Kinderhook, but on the opposite side of the Mississippi river) the Kinderhook shales from which no fossils had been reported were well supplied with organic remains, yet forms on the whole very different from those occurring higher up. It was soon seen that the fauna at the top of the Kinderhook formation was entirely distinct from that at the bottom of the section. This fact was made known in a paper* on the "Dual character of the Kinderhook fauna."

The problem of the exact relation of these two faunas demanded immediate attention. It was highly important to discover whether the two faunas gradually merged into each other, or whether the upper one abruptly replaced the lower one at a given horizon. The last-mentioned hypothesis was found to be the fact. In order to carefully determine this point, it was proposed to fix the vertical range of the various species composing the faunas, and thus to see not only exactly at what levels the forms disappeared, began, or replaced others. The splendid Louisiana section of rocks, of more than 300 feet in vertical measurement, was divided into twenty well marked lithologic platforms. Mr R. R. Rowley, who had long lived in the neighborhood and who had made extensive collections of the fossils, volunteered his services in the work. The results of the investigation are recorded in a joint paper† on the "Vertical range of fossils at Louisiana." Tables give the distribution of each species through the various layers. Out of 500 different forms, not a single one of those occurring in the lower part of the section was found to extend above the base line of the Chouteau limestone. Not a single species found in the upper portion of the section descended below the same level of the Chouteau. The fauna of the upper "Kinderhook"

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*American Geologist, vol. xx, 1897, p. 167.

†Proc. Iowa Acad. Sci., vol. iv, 1897, p. 26.

(Chouteau limestone) was in no way connected with that of the lower Kinderhook, but was inseparably connected with the higher or Burlington faunas. This last-mentioned fauna was, then, the fauna which Meek and Worthen * had partially studied, and, without any attempt to investigate thoroughly, had assumed as extending unbroken through the entire section of their Kinderhook formation.

Other phases of the problem brought out by the results of the examination of the Louisiana section were presented in some notes † on the "Relations of the Devonian and Carboniferous in the Upper Mississippi valley." The conclusions reached may be briefly stated as follows:

(1) The most marked changes in the succession of faunas in the entire sequence of rocks commonly known as the Lower Carboniferous or "Subcarboniferous," as represented along the Mississippi river, is at the base of the Chouteau limestone (limited). At this horizon there is so great a faunal break that scarcely a species is common to the beds on either side.

(2) That instead of the so-called Kinderhook containing in its fauna a mingling of Devonian and Carboniferous types, there are really two great faunas that are perfectly distinct and well defined, and do not merge into each other. In general aspects, the one is characteristically Devonian; the other strikingly Carboniferous.

(3) The basal line of the Lower Carboniferous, or Mississippian, series is the base of the Chouteau limestone, and the lowest member of the four-fold series contains only one formation, instead of three, heretofore commonly ascribed to it.

(4) The early reference of a part of the so-called Kinderhook, or "Chemung," to the Devonian was correct in fact, though made entirely through erroneous correlations and a misconception of the real facts.

(5) That the evidence afforded by the faunas of the region is in close accord with the facts obtained regarding discordant sedimentation and the stratigraphical and lithological characters of the formations themselves.

AFFINITIES OF THE LOWER KINDERHOOK FAUNA

So far as go the somewhat limited observations on the fossils of the Grassy Creek shales, their fauna appears to be identical with that of the lower Kinderhook at Louisiana. The prolifically fossiliferous layers of the Louisiana limestone are the shales separating the limestone layers at the very base of the formation. These shale partings, if they may be so called, are the same in all observable respects as the Grassy Creek shales beneath. When the latter come to be more thoroughly investigated it probably will be found that they carry a much larger variety of forms than is now known. All the most abundantly occurring forms of the lower Kinderhook and about half the total number of species are also found in the Grassy Creek terrane of the same locality.

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* Am. Jour. Sci. (2), vol. xxxii, 1861, p. 167.

† Trans. St. Louis Acad. Sci., vol. vii, 1897, p. 357.

Fifty miles southwest of Louisiana, on Snyder creek, near Fulton, in Callaway county, Missouri, there are, above the Callaway (Middle Devonian) limestone, 50 feet of green and blue shales. These are highly fossiliferous, and contain besides more than 100 other species, such forms as the following:

Acervularia profunda Hall.
Aulopora sp?
Leioclema occidens Hall.
Melocrinus lyelli Rowley.
Melocrinus gregeri Rowley.
Aristocrinus concavus Rowley.
Athyris minima Swallow.
Atrypa gregeri Rowley.
Atrypa hystrix Hall.
Atrypa reticularis Linnæus.
Crania crenistriata Hall.
Crania famelica Hall and Whitfield.
Cyrtina umbonata Hall.
Dielasma calvini Hall and Whitfield.
Hypothyris sp?
Leiorhynchus sp?
Megalanteris sp?
Orthothetes panaora Billings.
Pentamerella saliensis Swallow.
Productella callawayensis Swallow.
Productella marquessi Rowley.
Pugnax altus Calvin.
Schizophoria macfarlani Meek.
Spirifer asper Hall.
Spirifer annæ Swallow.
Spirifer euryteines Owen.
Stropheodonta altidorsata Swallow.
Naticopsis gigantea Hall.
Orthoceras sp?

These shales lie immediately beneath the Chouteau limestone, which is only a few feet thick at this point and is followed by the Burlington limestone with all its characteristic fossils. The Snyder shales appear to be stratigraphically continuous with the Grassy Creek shales In part, they may also represent the Hannibal shales.

The peculiar fauna having a strong Devonian facies, which has lately been discovered* in the Kinderhook shales, near the base of the exposed section at Burlington, Iowa, has already been noted.

The fauna of the highly fossiliferous layers at the base of the Louisiana limestone at the type locality recalls at once the familiar assemblage of depauperate forms that occurs near the top of the Cedar Valley limestone at so many places in Muscatine county, Iowa. Should, on critical comparison, the faunas of these two localities prove to be biologically the same, we would have additional evidence of the wonderful astuteness with which Hall surmised the faunal equivalency of the beds so widely separated geographically.

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* Proc. Iowa Acad. Sci., vol. iv, 1897, p. 38.

There are also many elements in the lower Kinderhook fauna of teh type locality and in that of the Grassy Creek shales underneath, that induce one to make careful comparison between them and the fauna of the Lime Creek beds of Iowa.

RÔLE OF CERTAIN FAUNAL ELEMENTS

The biological relationships of certain forms of fossils which appear to have an extended vertical range are of exceptional significance. An example is found in *Spirifer marionensis* of Shumard. This brachiopod is the most abundant and characteristic fossil found at the base of the Louisiana limestone. It ranges upward in constantly diminishing numbers to the top of the Hannibal shales. It has been often reported from higher horizons in southwest Missouri, especially, and at Burlington. The form going under this name as occuring in the Chouteau and its equivalents, does not appear to be *Spirifer marionensis* at all, but a species which at first glance has the same general appearance as that form· Although the distinction between the two shells has long been recognized, all have been called, in the Missouri reports, by Shumard's name, because, in the allusions made, the *S. marionensis* was a familar form, and absolute exactness or nice identification was not essential to the treatment of the themes then in hand.

The form in question was thought to be identical with that far-west shell described by White * from Nevada as *Spirifer centronatus* (not *S. centronata* of Winchell, 1865). The typical *S. marionensis*, Shumard, seems to find its closest affinities with certain Lime Creek spirifers.

That the suspicion of the identity of the so-called *Spirifer marionensis* from the horizons above the top of the Hannibal shales is well founded is further indicated by a recent statement † of Professor Weller, who is giving special attention to Kinderhook faunal studies. He says:

> "I have been coming to the conclusion strictly from the faunal evidence that the strata representative of the Louisiana limestone at Burlington must be lower down than I had first suspected. I have looked for the Spirifer marionensis fauna at Burlington, and was at first inclined to identify the common spirifer in the oolite bed with this species. This identification led me to place the horizon of the Louisiana limestone higher than I would otherwise have done. I am now convinced, however, that *S. marionensis* does not exist at Burlington, at least in the collections I have been able to study. I now identify this oolite species with that which has been described from the far west as *S. centronatus*. Whether it is Winchell's original *S. centronatus* from Michigan I do not know, having never seen authentic specimens from there and it never having been illustrated. The spirifer

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* Geog. and Geol. Survey, west of 100th Merid., 1877, p. 86.

† Communication.

from southwest Missouri, which has usually been identified as *S. marionensis*, is also, I think, *S. centronatus*."

INTERVAL FAUNAS OF THE OZARK REGION

On the northwest flank of the Ozark uplift, where the Interval deposits are wanting, the fauna of the original Chouteau limestone directly succeeds an Ordovician fauna. Farther southward in southwest Missouri intermediate faunas become intercalated.

It has long been known that faunas comparable to those of the Chouteau limestone, Hannibal shales, and Louisiana limestone occur in this region. Shumard * and Swallow † early recognized there fossils belonging to these zones. The later work of the Missouri Geological Survey throws much doubt on the possibility of the extension of the typical Louisiana into the southwestern part of the state, ‡ though the peculiar fauna of the formation is fully recognized. On the other hand, § it is believed that the Hannibal shales are stratigraphically continuous with the similarly named shales of the southestern part of the state. All later evidence seems to bear out the correctness of this supposition.

Still more recently Professors Weller‖ and Williams ¶ have given the results of their studies of the fossils which they found in the formations of southwest Missouri and northern Arkansas. The most noteworthy horizon below the Burlington limestone is the black Eureka shale. The organic forms recorded from this formation are far too few in number to base any very important or exact faunal correlations. The Eureka terrane has been generally regarded as Devonian in age. Both of the authors just mentioned are inclined to put the formation considerably higher up—in the Carboniferous. The first named would have these shales represent the typical Chouteau limestone of central Missouri, while the other would parallel them with the typical Louisiana limestone.

I can well agree with the views of Professor Williams on this point, but with this explanation. At the time at which Professor Williams wrote the fossils of the Louisiana limestone had never been obtained higher than a few feet above the base of the formation, in the shale layers which there alternate with the lower layers of the limestone. This was the known horizon of what is called the Louisiana fauna. It is really the fauna of the black and green shales underlying. I am not aware that any fossils were ever obtained from any part of the Louisiana limestone, except the very base, prior to the recent efforts to collect them from the higher horizons, made by Mr Rowley and myself. The main body of the Louisiana limestone is almost devoid of organic remains. With this understanding, the fauna of the Eureka shale, so far as it is now known, may be made the correlative of that at the basal layers of the Louisiana limestone. I had already come to this conclusion independently and some time before Professor Williams made his trip to Arkansas. The only difference between us on this point is that I reached my own conclusions along somewhat different lines.

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* Missouri Geol. Survey, 1st and 2d Ann. Repts., 1855, p. 103.

† Ibid., Repts. 1855–'71, p. 207.

‡ Missouri Geol. Survey, vol. iv, 1894, p. 52.

§ Ibid., p. 57.

‖ Journal of Geology, vol. ix, 1901, p. 130.

¶ Arkansas Geol. Survey, Ann. Rept. 1892, vol. v, 1900.

Both Professors Williams and Weller have unintentionally somewhat strained the facts in their identifications of species by comparing them only with stratigraphically higher forms. Comparison with the lower and older species gives very different results. Nearly all of the forms enumerated by the authors mentioned, besides many other species that were collected, were carefully compared more than a dozen years ago, during the progress of the Missouri geological survey in the southwestern part of the state. The deductions then reached were to the effect that the closest affinities of the various organic remains represented were to be found in the earlier forms rather than in the later. It appears beyond all doubt that some of the species listed by the authors referred to do not occur so low as the horizon of the Eureka shale.

Williams places the Sylamore sandstone, a part of the Black shale (Eureka shale in part), and certain green shales which occur in northern Arkansas, in the Devonian. He considers these to represent all the deposition that took place during that time.

The rounded and highly polished "pebbles" which are so widely distributed through the black and green shales I have regarded as chiefly coprolitic in character. In certain layers they occur abundantly with fish teeth and fish bones. Many of them are highly phosphatic in nature.

While the basal limits of the Devonian in the northern part of the Mississippi valley have long been definitely located, the nether delimitation in the Arkansas region has, until very recently, remained undetermined. Professor Williams has shown beyond all reasonable doubt that the great Saint Clair limestone comprises in reality two distinct faunas—a lower one that is Ordovician and an upper one which is Silurian. The latter is what is generally known as the Niagara fauna, and limits the Devonian downward.

CHARACTER OF THE TRANSITION ZONE

There is a zone of indeterminate extent that, so far as its faunal features go, is often claimed as being undetermined as to geological age.

It is frequently called the Devono-Carboniferous zone. The general assertion is that it can not be referred to either one of the two great systems. Only the bare statement exists and is reiterated. The facts as now known give small grounds for the assertion.

If the basal plane of the Carboniferous be taken as the bottom of the original Kinderhook, the forms of the succession of layers certainly do appear to be in unbroken sequence. According to the evidence here presented, the succession of fossils clearly indicates that the faunal occupancy of the region was at that time more than merely sequential—it was genetic.

If, however, we proceed on the hypothesis that the base of the Chouteau limestone should be considered the real bottom of the Carboniferous system, we find an entirely different group of circumstances prevailing. The higher fauna is manifestly not the direct genetic successor of the lower one. It is essentially alien. The biotic change at this level is as abrupt as the lithologic one. There is practically no transition zone at all. The line demarkating the faunas is sharply defined. There are, moreover, physiographic reasons for believing that an important stratigraphic line should be here drawn.

In southwest Missouri, where the mergence of faunal elements into a Devono-Carboniferous zone has been most urged, similar conditions and similar facts appear to obtain. A mingling of faunas in the zone under consideration may be a feature, but it is a feature that never has impressed any one who is familiar with the faunal elements of the more northern strata generally called Devonian. Moreover, as already stated, Williams* has recently urged the faunal parallelism of the Sylamore sandstone and the accompanying shales of Arkansas with the Louisiana limestone of northeast Missouri. When it is remembered that the described fauna of the Louisiana limestone is really the fauna of the shales underlying, the real force of this statement will be at once apparent.

The character of the so-called transition zone is viewed in another light from that which it has been ordinarily when it is considered that the present Ozark uplift has not been a land elevation ever since pre-Cambrian times, but, as recently † shown, is of comparatively late origin.

PECULIARITIES OF THE ORIGINAL KINDERHOOK

The main reason for the general confusion which has so long prevailed regarding the limitations of the formations here regarded as properly belonging to the Interval deposits is no doubt the lack of exact field data relating to the range of the various faunal elements. As already stated, this misunderstanding has been particularly noteworthy in the case of the original Kinderhook. The faunal relations of the several parts of this rock sequence have been fancied rather than real. The actual distribution of the fossils has anomalies and peculiarities that were wholly unlooked for.

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*Arkansas Geol. Survey, Ann. Rept. 1892, vol. v, 1900, p. 318.

† Science, N. S., vol. vii, 1898, p. 588.

As in the case of the great Ozark series, the original Kinderhook certainly belongs partly to one great system and partly to another. The term Kinderhook can not be modified so as to be made to apply to either part. As a formational name, it is best dropped altogether, except in historical reference.

The Chouteau fauna of Williams is not the fauna of the original Kinderhook beds. It is essentially the fauna of the original Chouteau limestone, notwithstanding the assertions of its greater extent. As such, it is a valuable unit of both the faunal and rock scales in the taxonomy of Mississippian stratigraphy.

The original Kinderhook formation of Meek and Worthen is not a geological unit, compact, definitely defined, and geologically useful; but a medley, unreal, and non-correlative.

EVIDENCES OF UNCONFORMITIES

A decade ago[*] it was suggested that the evidence acquired during the prosecution of the Missouri geological survey indicated that the Carboniferous rested unconformably upon the Devonian of the region. While it is not germane to the present theme, it may be stated that many additional data bearing upon this point have been, of late, obtained. The original Chouteau limestone appears to be the lowest member which was generally regarded as belonging to the Carboniferous that displays unconformable relationships with the strata underlying.

Attention has been called to the fact that west of Clinton, in west-central Missouri, the Chouteau limestone rests on Ordovician rocks; that eastward from the type locality of this limestone it rests on Devonian shales carrying such forms as *Atrypa recticularis*, *Orthis impressa*, etcetera. Thus, in this region, as shown by Marbut,[‡] the shales which are equivalent to those below the Chouteau limestone in northeast Missouri, all the Devonian, and the Silurian ("Niagara"), are wanting.

To the south, in southwestern Missouri, Devonian strata again appear. In northern Arkansas, Williams has lately demonstrated that both the Devonian and Silurian beds are present. On the east side of the Ozark dome, along the Mississippi river, both Silurian and Devonian sequences are unbroken.

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[*] American Geologist, vol. x, p. 384, 1892.

[†] Missouri Geol. Survey, vol. xii, pt. ii, p. 121, 1898.

It has thus been assumed that the Devonian beds form one of the concentric zones around the older central rocks of the Ozark dome. On this account chiefly it has been urged that the Devonian sediments were laid down around the margins of what is titled the Ozark isle. The necessary inference has been that during Devonian times subaerial erosion took place over the Ozark region.

Attention to a few facts quickly shows the fallacy of such a hypothesis. The Devonian sediments themselves display nowhere a coarse littoral character. The "concentric ring" is not an unbroken one; it is sundered on the southeast and in the northwest portion. Devonian deposits, highly fossiliferous, occur on the highest part of the Ozark uplift, proving beyond all doubt that in the absence of other evidence they extended undisturbed over the entire dome. It is clearly manifest from geographic inquiry that the present Ozark uplift is a very recent uprising—probably post-Tertiary.

In the face of these facts, the hiatus in central Missouri has an unusual significance. It points at once to the suggestion that the area in which there was no Devonian deposition was not a subcircular belt coincident with the present flanks of the Ozark dome, but a more or less linear district—a narrow ridge, so to speak. The structure of the Ordovician beds of the region also indicates that this is the true explanation. As long ago as 1892 I called attention to the location of this old ridge. Today its importance appears much greater than had previously been supposed.

Comparative Values of correlative Methods

Not nearly enough detailed work has yet been done on the fossils to enable exact correlations to be made through the faunas alone. Were it not for the adoption of other and independent methods of correlation, the strata of the region, so far as the paralleling of the different vertical sections is concerned, might for a long time yet remain in a very unsatisfactory condition.

In the correlation of the strata five distinct methods have been made use of. In consequence the results obtained by one method have been checked by those arrived at through other independent data. In this way marked discrepancies in the readings of one set of records have been detected and corrected. The values of the several methods have been quite different in different localities, but when all could be applied in a single district the comparative results have been full of interest. This has been particularly notable in the case of northeast Missouri in the area occupied by the original Kinderhook.

In order of their practical values in the field work in this district, these five methods are similarity of lithologic sequence, lithologic similarity, faunal comparison, orotaxis, and homogeny.

Recapitulation

From the foregoing the following conclusions may be briefly stated:

(1) The sediments of Missouri and the neighboring states, regarded as Devonian in age, form a well defined terrane that is delimited in a remarkably clear manner both above and below.

(2) Over the area now occupied by the Ozark dome the Devonian sediments were deposited much in the same manner as farther northward, and not around the borders of an Ozark isle.

(3) The gap in sedimentation during the Devonian interval must be more largely and widely represented to the west of the present line of outcrops along the western flank of the Ozarks.

(4) The original Kinderhook formation is not a homogeneous terrane, but is composed of parts of two very distinct systems.

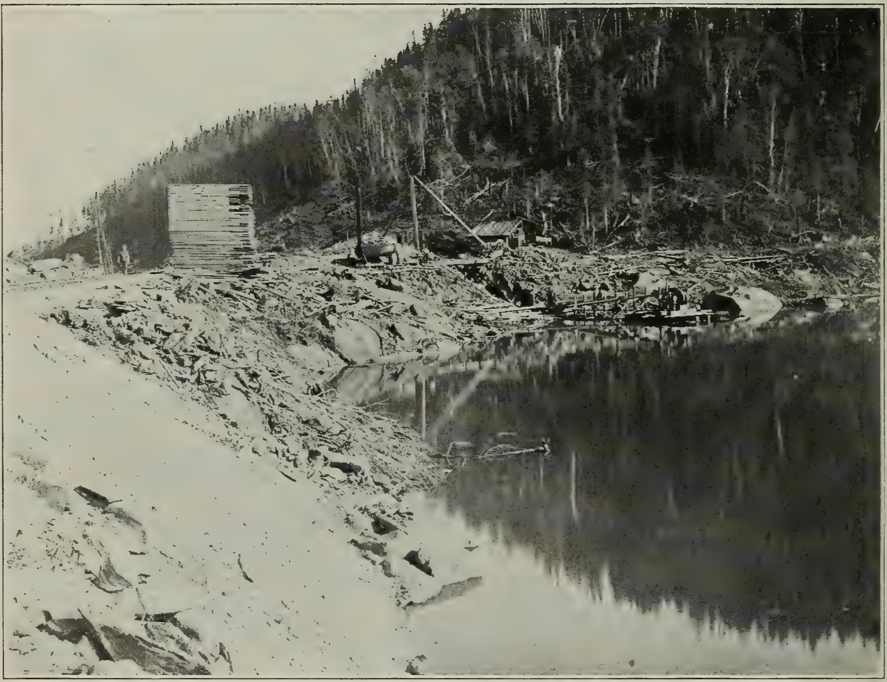
(5) The median shale of the original Kinderhook is stratigraphically continuous with an undoubted Devonian shale, and the two appear actually to form parts of a single formation, which above the mouth of the Missouri river contains in its middle the Louisiana limestone.

(6) The so-called Chouteau fauna is a composite fauna, and not the fauna of the typical Chouteau limestone of central Missouri.

(7) Many of the fossils that have been reported from the Chouteau limestone in central Missouri are now known to be not from this terrane, but from an entirely different formation.

(8) A remarkable plane of unconformity appears to exist at the base of the typical Chouteau limestone, the full significance of which is as yet undetermined.

(9) Instead of a complete mingling of the different elements of the faunas at the juncture of the Devonian and Carboniferous making up a Devono-Carboniferous zone, so to speak, the biotic changes of the two systems are rather sharply contrasted.



WEST END, BOYER LAKE, HELEN MINE

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
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ROCK BASINS OF HELEN MINE, MICHIPICOTEN, CANADA

BY ARTHUR P. COLEMAN

(Read before the Society January 1, 1902)

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INTRODUCTION

Among the thousands of lakes in Canada there are hundreds that are apparently rock-rimmed, having their outlet over sills of solid rock and having shores of rock in most places; but generally there is some drift-covered point in the circumference of the basin where an old channel may be concealed. It is not often that one can actually trace the solid rock entirely round the shore with no point hidden. This is the case, however, with the two small lakes near the Helen mine which are to be described in this paper.

The causes of rock inclosed basins are various, most of them in Canada being due to glacial action, the rock surface having been excavated by the ice unequally, probably because of preglacial decay having extended to unequal depths, though it was commonly believed in earlier times that undecayed rocks could be deeply eroded by ice, and that even basins like that of Ontario could be excavated by it.

It is now well known that glacial ice may pass over unconsolidated drift material with little or no effect in the way of excavation, especially near the margin of an ice-sheet where it has grown thin, and that excavation into solid rock is to be expected only under special conditions—for instance, where the ice is thick and its action directed toward certain points by the shape of its bed.

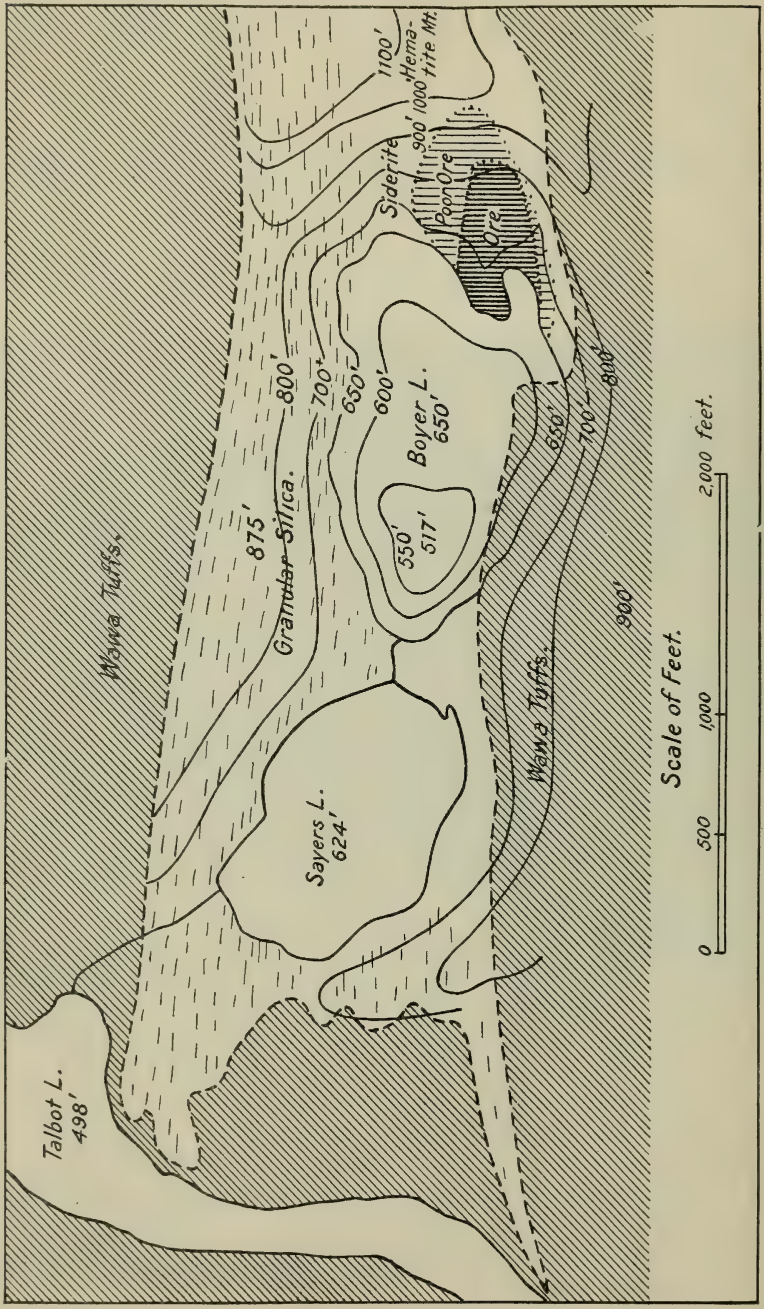
Wawa Tuffs.
875'
Granular Silica.
1100'
1000'
900'
Hema-tite Mt.
Siderite
Poor Ore
Ore
800'
700+
650'
600'
Boyer L. 650'
550'
517'
Sayers L. 624'
Talbot L. 498'
Wawa Tuffs.
650'
700'
800'
900'
Scale of Feet.
0
500
1,000
2,000 feet.

FIGURE 1.—*Geological Map of Helen Mine.*

Our largest rock basin, that of Superior, is explained as a synclinal depression, probably of very ancient date, and a number of other large lakes, like Ontario, are supposed to have been formed by differential elevation, the lower part of a river valley being raised so as to pond back the water. Still others are explained as produced by faulting, blocks having slipped down during readjustments of equilibrium, as some geologists hold regarding the deep lake expansions of the Ottawa chain of waters.

None of these explanations can apply to the two small basins at the Helen mine, and the theory of solution seems the only one that is satisfactory.

TOPOGRAPHY

Lakes Boyer and Sayers occupy most of the floor of a narrow valley, at the east end of which is the Helen iron mine. The region is near Michipicoten bay, on the northeast side of lake Superior, and has the usual rugged character of that shore, but is easily accessible by the railway, twelve miles long, connecting the mine with the ore docks. This and the mining operations provide good opportunities to study the relationships of the lakes.

The outlet of the valley is 624 feet above lake Superior, according to the railway levels, though only 7 miles in a straight line from the shore, and there is a fall of 126 feet in less than 300 yards to Talbot lake, which represents the general level of the neighboring valleys.

The Helen Mine valley is a narrow trough, three-quarters of a mile long and less than a quarter of a mile wide, running about east and west and opening northwest toward lake Talbot. The walls of the valley rise steeply to a height of 200 feet or more on the north and south, while the east end is closed by Hematite mountain, much the highest point in the region, rising 450 feet above the valley and 1,100 feet above Superior. Climbing up from lake Talbot, which is 498 feet above lake Superior, the small stream draining the valley above becomes more and more rapid till, after plunging over the few feet of rock which hold in Sayers lake, it is a succession of short falls. This small lake or pond is 624 feet above Superior, 1,200 feet long, and 600 feet wide, and is followed toward the east, after a dam of rock 200 feet across, by Boyer lake, 650 feet above Superior, about 1,700 feet long, and half as broad. To the east of Boyer lake is the ore body, which rose about 100 feet above it before mining operations began, and behind it is Hematite mountain. Boyer lake has been carefully sounded, and before it was partially drained to facilitate mining was 133 feet deep, with, however,

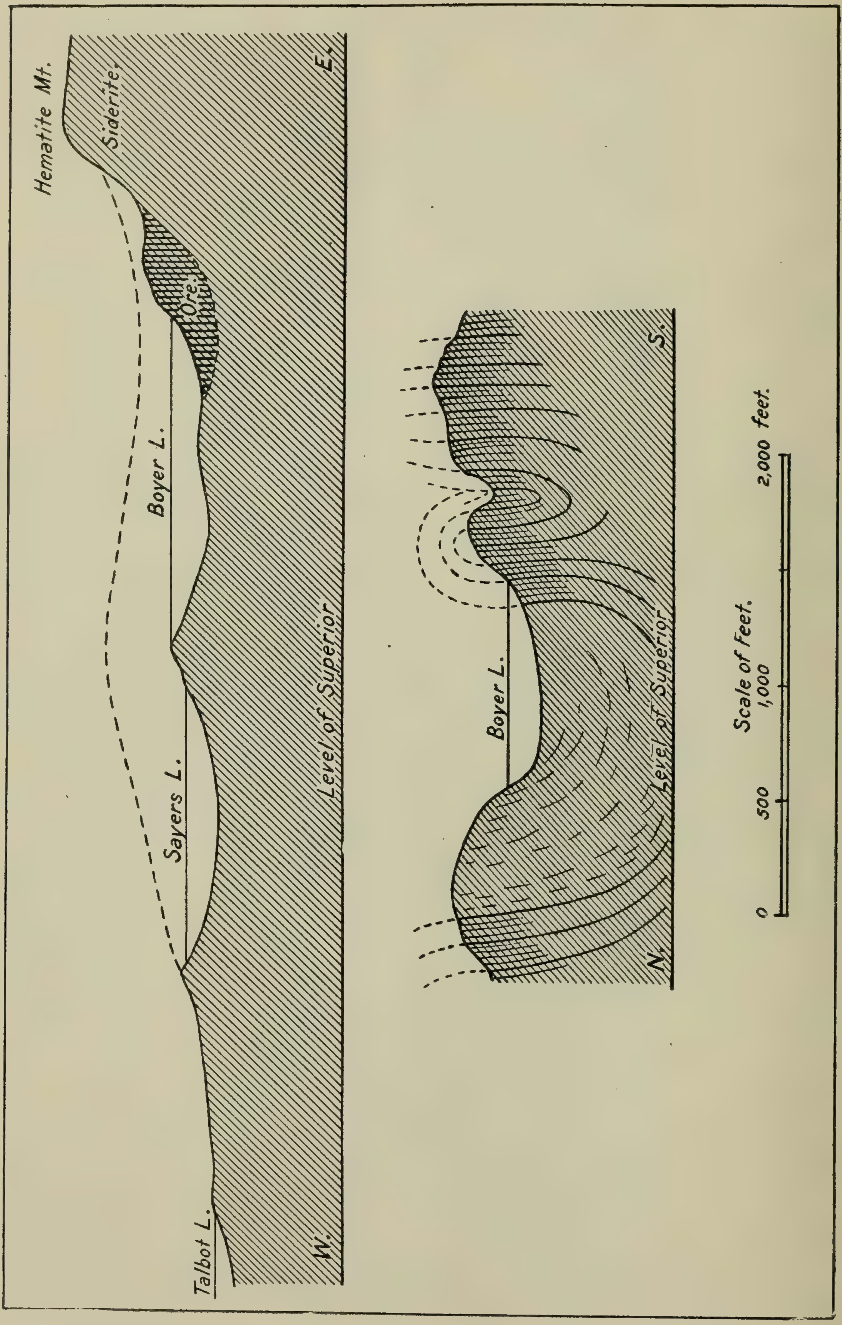
Hematite Mt.
Siderite
Ore
Boyer L.
Sayers L.
Talbot L.
Level of Superior
E.
W.
Boyer L.
Level of Superior
S.
N.
Scale of Feet.
0
500
1,000
2,000 feet.

Figure 2.—Sections near Helen Mine.

from 20 to 60 feet of slimy mud covering the rock bottom. This lake has no visible tributaries, but is, of course, fed by the rainfall of the upper end of the valley. The small stream flowing out of it has not cut any appreciable channel, and the same is true of the stream from Sayers lake, which is stated to be about as deep as Boyer lake and with the same muddy bottom. One can walk round both lakes with solid rock in sight the whole way, so that there can be no doubt that the basins are inclosed by rock. In a few places the rock shelves gently into the basins, but generally forms steep slopes or even cliffs at the water's edge.

Geological Conditions

In order to understand how the valley was carved it is necessary to give an outline of its geological structure. The lake basins are almost entirely inclosed in rocks of the Lower Huronian iron range—granular silica interbanded with iron ore toward the north, and the same with pyrite or else siderite toward the south. The steep slope of Hematite mountain and its summit consists chiefly of somewhat pyritous and silicious siderite. On each side of the band of iron range rock, which is about 1,000 feet wide, are greenish schists, mainly sheared quartz-porphyry—the rock usually found underlying the iron range in the region. Part of the southern shore of Boyer lake consists of the quartz-porphyry schist, with a narrow dike of greenstone, now schistose also, so that its basin is not wholly inclosed by the iron range. The northern side of the iron range is very hard and cherty or quartzitic and has resisted the weather even better than the schist, so that it forms the highest part of the ridge.

The eastern end of Boyer lake does not reach the foot of Hematite hill, since that part of the basin is occupied by the ore body which will be referred to again.

Professor Willmott, who has studied the geology of the Helen mine in detail, represents the arrangement as synclinal, toward the western end complicated by the rising of a small anticline in the middle. The iron range is, of course, inclosed and folded within the thick series of schists forming the bulk of the Lower Huronian, and the date of the folding is very ancient, almost certainly pre-Cambrian. When the folding took place we can imagine the tough schists as yielding without much breaking; but the more brittle iron-range rocks were greatly crushed, and a large amount of breccia was formed of fragments of granular silica, as may be seen along the north of the basin, especially on the shore of Sayers lake.

The crushing took place after the silicious part of the iron range had consolidated in the shape of polygonal crystalline grains, but before the deposit of granular silica was complete, for the angular fragments of white "grained" silica are cemented by less pure brownish silica having the same structure. It is probable that the crushing of the iron-range rocks was one of the most important factors in the hollowing of the valley and its rock basins, since it gave opportunities for the circulation of fluids.

Probable Causes of the Rock Basins

We are now prepared to consider the forces which excavated the basin. It is evident that ice has done a great amount of work in the region, since blocks of ore weighing several tons are found on top the ridge toward the south, no doubt transported from the mass of ore beneath, now forming the mine at the east end of the valley, and it is also clear that the ice had at least some effect at the very bottom of the valley, for a shelving point of rock on the south side of Boyer lake, exposed by the partial drainage referred to before, is smoothed and striated, the motion of the ice being in a direction 10 degrees east of south across the strike of the schists and the direction of the ridges on the north and south.

However, the action of ice can have had little effect in scouring out a trough which lies transverse to its direction of motion, and there is good evidence to prove that the original hollowing of the valley took place, at least in part, long before the Glacial period, for the great ore body which occupies its eastern end is pre-Glacial in age, as shown by the erratic blocks of ore to the south and by the finding of glacial striæ on top of the hill of ore by Doctor Bell.* The shape of the valley, with its steep, sometimes almost vertical, northern wall, is such as could not be accounted for by the action of ice coming from the north, though a flow of ice toward the west, of which there is no evidence, might have done work of the kind.

Nor can we consider running water capable of cutting the valley with its rock basins unless under conditions very different from the present; for the whole surrounding region is distinctly lower than the rock walls of the valley, which slope away in all directions, except along the narrow ridge of Hematite mountain, and afford no opportunity for a stream to enter the valley. At present there is no stream flowing into Boyer lake, and the small stream flowing out of it represents only the rainfall of the valley itself. It has done practically no work since the Ice age, though running over a somewhat decomposable rock, silicious siderite, heavily charged with pyrites and sometimes also pyrrhotite, and the same is true of the slightly larger stream draining Sayers lake into Talbot lake, which begins its course by tumbling over rock very similar to that at the outlet of Boyer lake. In any case, one could not imagine any stream short of a powerful waterfall excavating such deep basins, 133 feet below the level of the outlet, even if it had previously dug the valley down to its present slope.

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*Geol. Survey of Canada, Summary Rept., 1900, p. 116.

There is no evidence of late faulting to produce the basins, and warping of the crust is out of the question for cavities so small; so that we are reduced to solution as their cause.

The materials inclosing the basins are largely of a soluble kind—siderite, pyrite, pyrrhotite, and iron oxides—but there must have been a very large amount of silica removed also and of a very insoluble variety, for the granular silica of the iron range is not opaline nor even chalcedonic, but distinctly crystalline, as seen in thin sections, and not only the banded rock, but also the massive siderite, contains a considerable percentage of these quartz grains, which have to be disposed of in some way. In connection with this it may be mentioned that a pale-gray, flour-like silt found in large quantities a few miles southwest of the mine consists of silica, no doubt derived from the iron range, though not necessarily from this part of it.

The Action of Solvents

The solvent that one thinks of first is carbonic acid, obtained by surface waters in the soil of the hills around, and this is no doubt capable of attacking the impure carbonate of iron which formed a large part of the rock to be removed. It is a curious fact, however, that the summit of Hematite mountain, the highest point for many miles, consists of siderite which has been weathered to the depth of a half inch, or at most a few inches, since the Glacial period, but has not been removed bodily, since there still remains a crust of limonite well shown in certain costean pits across the top of the ridge.

The only other solvent likely to have been present is sulphuric acid, resulting from the action of water and oxygen on the pyrites distributed in large amounts through all the country rocks of the valley and forming more than half the volume of the rock at some points, as on the south shore of Sayers lake, where a prospector has driven a tunnel into the pyritous mass. However, caution is necessary in assuming that products of the decomposition of pyrites were the only important solvents, for it is often found that inside a mass of siderite completely changed to limonite the crystals of pyrites are almost untouched. Evidently the pyrite is not very readily decomposed, though the pyrrhotite found in some parts of the valley is attacked rapidly.

The solvents mentioned, carbonic acid and sulphuric acid, appear to be the only ones which could be brought to bear under all the conditions, unless the work was done at considerable depths, when water, under pressure and more or less heated, would become an effective solvent, which might attack the silica as well as the other components of the rock. The last supposition, which seems very probable in early times, when the breccias of granular silica were cemented with fresh silica, can not hold for later times, when the valley was open to the air.

Supposing the solvents at hand, why should certain parts of the iron range be attacked and removed, while others, such as the top of Hematite mountain, have shown a very high degree of resistance? Two reasons suggest themselves to account for this: The shattering of the iron range during the folding process was apparently quite local, and at the shattered points waters charged with solvents could circulate, while they were excluded from the unshattered portion of the range; and again, the materials of the iron range over the two basins may have been different in composition from the rest and more easily attacked—for example, there may have been unusual quantities of pyrrhotite at those points. It is not impossible that both assumptions are true, for the pyrrhotite which still occurs between the two lakes on the north side of the valley is not a strong nor tough ingredient of the rock, and if present in large quantities would probably render it more frangible than the adjoining rock, as well as more soluble.

Relation of the Iron Ores to the Basins

A thorough understanding of the processes which made the great mass of iron ore at the east end of Boyer lake would, no doubt, help greatly in explaining the origin of the valley and its rock basins, and a brief study of the known facts will be of service here. Unlike most of the ore deposits of the iron ranges of Michigan and Minnesota, the ore of the Helen mine is completely free from any capping of silicious iron-range rock. Following the account of Professor Willmott, who has studied it carefully, it stands as a separate hill, sloping in all directions from the center and rising 100 feet above the original level of the lake, covered, however, to some extent round the edges, toward the north, east, and south, by boulder clay and debris rolled from the walls of the valley. The ore, which consists of hematite mixed with limonite, is of a somewhat open, porous character, the walls of the cavities being lined with more or less concretionary or stalactitic limonite, and from its arrangement appears to have been formed partly of loose fragments of siderite or of silicious iron-range rock changed to oxides in their present position, and partly of limonite deposited in a stalagmitic way from solutions which probably encountered here a current of water charged with oxygen.

Professor Willmott considers that the cavities in which the ore was deposited were formed by the folding of the rocks and solution while the iron-range rocks still covered what is now the valley to the extent of hundreds of feet above its present level. This does not explain, however, the way in which the overlying rock was removed from the valley and prevented from filling the two lake basins.

Following this view, we might imagine all the iron to be removed in solution, when not precipitated by meeting oxygenated currents, as at the present ore body; but the removal of the silica, which exists to the amount of 5 or 10 per cent in even the purest parts of the siderite, is not accounted for, and one would expect to find the rock basins filled with finely granular silica, like certain bands of pure-white sand occurring in the ore body as a residuum from the solution of the siderite.

In accounting for the replacement of silica by iron ore in the Michigan mines, Professor Van Hise* and other geologists have supposed that alkaline waters have been the chief agent, and there is no doubt that silica may be removed in that way, especially when the water is warm; but it is not easy to imagine such solutions at work after the valley containing the two lakes here described was open to the sky, and the basins could not have been completed before that time, or the fragments of the overlying undissolved part of the iron range must have filled them when the final collapse took place.

There is no known source of alkaline solutions in the valley at present, for the iron range, which includes most of the inclosing rocks, is singularly poor in alkalies, and the immediately adjoining quartz-porphyry schists are themselves largely silicified and charged with carbonates.

It is possible that the valley was cleaned out by the action of a stream flowing through it at a remote time when the surrounding country had not been cut down to its present level, but there is no evidence at hand to prove this, and the carving of the basins below the level of the outlet of the valley could not be accounted for in this way. On the whole, it seems more probable that the slow action of the weather and of the little stream representing the local drainage cleared out the valley after subterranean leaching had progressed far, crumbling the brecciated rocks which filled it, and that when this process was complete or nearly so the basins were excavated in parts of the bed more easily soluble than others, the carbonates of iron, lime, and magnesia, which make up nine-tenths of the rock, being removed* and the silica left behind in the basins as part of the green mud covering the bottom to depths of from 20 to 60 feet. An analysis of this mud, made in the laboratory of the Lake Superior Power Company, at Sault Sainte Marie, Ontario, showed that more than 47 per cent of it is silica, the next largest solid ingredient being iron, which forms 11 per cent.

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*U. S. Geol. Survey, Mon. xxviii, Marquette region, p. 403.

This account of the hollowing of the lake basin seems to conflict with Professor Willmott's theory of the formation of the ore body, which he supposes to have been deposited in a cavity or cavities before the overlying iron-range rocks had been removed, for the ore apparently occupies the east end of the Boyer Lake basin, and, if so, must have been deposited after that was formed. It may be, however, that the ore, which has been found by boring to go 188 feet below the original lake level, represents largely or entirely the oxidation of siderite in place, and that the lake basin is later in age and formed partly by solution of the ore itself.

It is of interest to note in this connection that iron is still going into solution and still being deposited in the basin, for at the east end of the lake, north of the ore body, a considerable thickness of bright yellow ocher containing 49½ per cent of iron, was discovered when the water was lowered by cutting down the outlet, evidently a distinct and much later deposit than the ore of the mine, since it rests in part on the lower slope of the mass of ore. In addition all the rock surfaces which had been below water are covered with a film of bog or lake ore, which in some places forms flat concretionary rims at certain levels or round cakes a few inches across and half an inch thick in the upper part of the green mud. These deposits represent work done since the Ice age, for they are found on glaciated surfaces and on drift boulders; and if we multiply the thousands of years since the ice departed to equal the millions of years of pre-glacial action, perhaps the present rate might account for the great mass of ore at the mine, if all was accumulated at one place instead of being spread over the basin. Whether more ma-

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*See Bureau of Mines of Ontario, 1901, p. 193, for analysis of the siderite:

	1.	2.
Insoluble	4.38 per cent.	14.76 per cent.
Carbonate of iron	78.57 " "	74.07 " "
Carbonate of magnesia	12.84 " "	8.75 " "
Carbonate of lime	4.09 " "	0.79 " "
Total	99.88 " "	98.37 " "

terial is now being dissolved from the basins than is deposited in them, there is no means of deciding.

Age of the Rock Basins

The age of these two remarkable rock basins can not be very precisely determined, all that is certain being that they are post-Huronian and pre-Glacial. No rocks later than the Keweenawan eruptives and conglomerates and the immediately overlying Lake Superior sandstones are known in the region. If the latter once covered the Helen mine, the age of the basins must be post-Cambrian; but the horizontal sandstones often found around the shores of Superior have never been reported at a level so high as 650 feet above the lake, at least on the north shore, so that the erosion of the region probably began before the Cambrian. It is probable that the Archean mountains, whose stumps are no doubt represented by the Laurentian granites and gneisses, with Huronian synclines sharply nipped in between, have never been buried under later rocks, in which case the shaping of the topography may have begun with the Paleozoic.

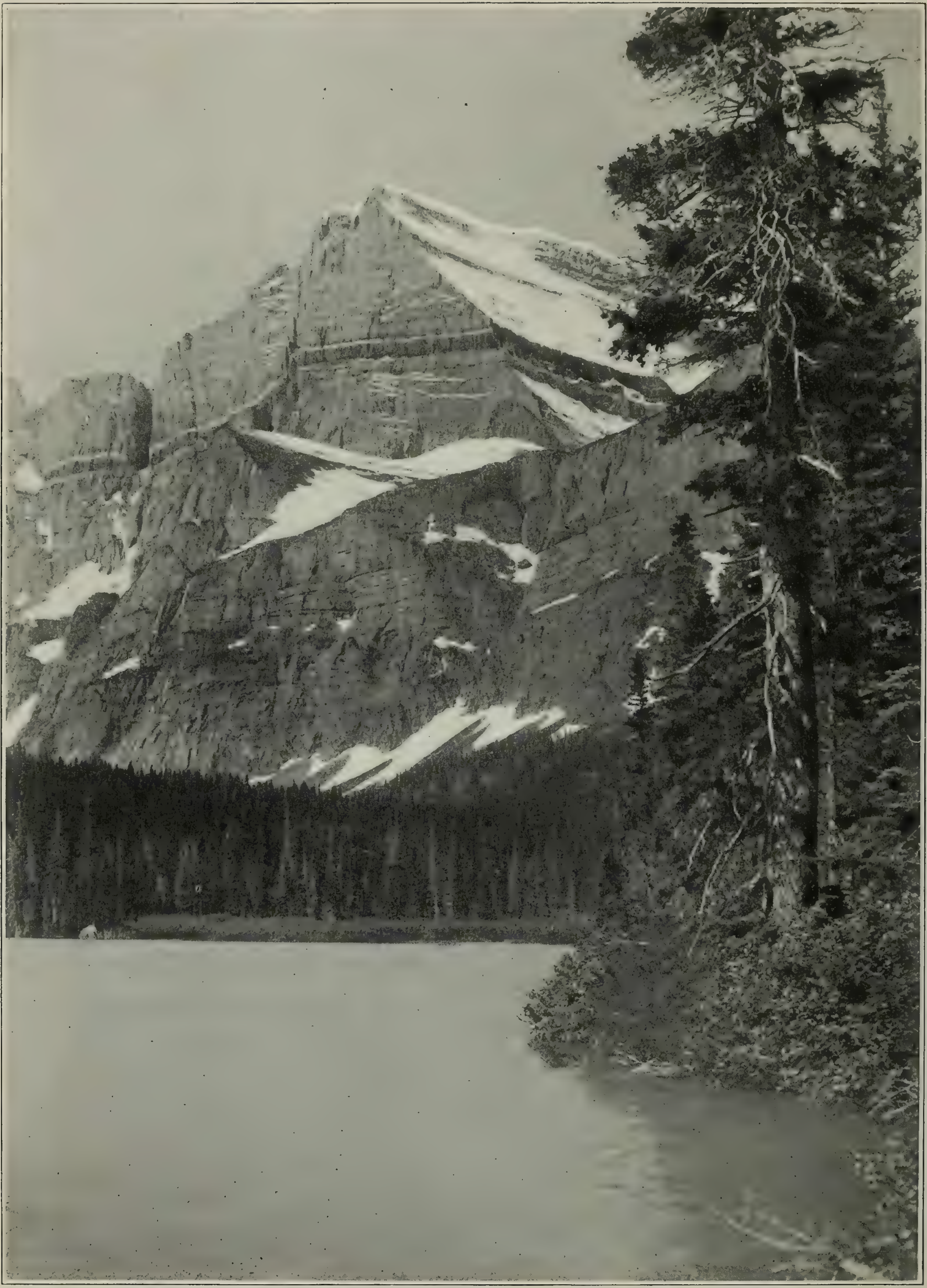
The formation of the million tons of iron ore at the mine toward the eastern end of Boyer lake must have been a very slow process, and if the basin was complete before its deposit was commenced it may even be Paleozoic in age; but if the ore was there before the basin, as seems more probable, and was partly dissolved and removed in its formation, the date assigned will be very much later. When the mine is worked at lower depths than now we shall probably learn with more certainty the relationships of the ore body to the lake basin and be able to solve some problems now left open.

One naturally asks if the rest of the basin of Boyer lake was once filled with ore, since dissolved away, and if the basin of Sayers lake also once contained ore; but this question can hardly be answered at present. No doubt much iron ore has gone down the valley in solution, for the beds of sand forming lake terraces near Michipicoten harbor are often cemented with limonite over wide areas; but this is of course a comparatively modern deposit, certainly post-Glacial, and has little to do with the early history of the rock basins.

We may safely say that the two deep ponds at the Helen mine occupy basins very much more ancient than those of most other lakes in Canada, to be compared in age with such profound cavities as the one occupied by lake Superior rather than with the tens of thousands of large and small basins produced by the Glacial period.

In closing this paper, acknowledgments must be made to the Messrs Clergue and their engineers at the mine, and also to Professor Willmott, for their great kindness in supplying information and for the use of maps and sections prepared for purposes in connection with the mine.

It is now very easy to reach these extraordinary little rock basins by steamer and railway from Sault Sainte Marie, and the region presents an unusual variety of interest to the geologist and geographer, as well as to the mining engineer.



MOUNT GOULD, LEWIS RANGE

From South Fork of Swift Current, looking southwest. A characteristic cliff of Siyeh limestone overlying Grinnell Argillite; dark band of intrusive diorite. The valley is a glacial amphitheater typically developed on joint plains. From lake to summit, 4,670 feet.

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STRATIGRAPHY AND STRUCTURE, LEWIS AND LIVINGSTON RANGES, MONTANA*

BY BAILEY WILLIS

(Presented before the Society January 1, 1902)

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SYNOPSIS

The facts stated in the following article relate to the Front ranges of the Rocky mountains in Montana and adjacent Alberta, between the Great plains and the valley of North Fork of Flathead river. The Front ranges are two—Lewis range, which, rising from the Plains across northern Montana, extends into southern Alberta and ends, and Livingston range, which, lying 8 to 15 miles west of the Lewis, becomes in Alberta the easternmost height of the Rockies. The features of adjacent districts are described so far as they bear on the main subject, the stratigraphy and structure of the Front ranges.

Lewis and Livingston ranges consist of stratified rocks of Algonkian age, as determined on fossils which were found by Weller in the lowest limestone of the series and identified by Walcott as probably being *Beltina danai*, the species of crustacean discovered in the Grayson shales of the Belt mountains. The Algonkian series consists of limestone, argillite, and quartzite, classified in five formations. There is a certain degree of repetition in the general phases of sedimentation; limestone is succeeded by argillaceous and quartzitic beds, which are surmounted by a considerable thickness of highly ferruginous red sediments, and a second great limestone also is followed by quartzite and argillite, the last named being again of a deep red color and carrying casts of salt crystals. There is apparent conformity throughout. The series is so situated with reference to other rocks that no lower or upper stratigraphic limit could be determined. Dr G. M. Dawson classified the strata as Cambrian, Carboniferous, and Triassic, but it is believed that he mistook certain local overthrust faults for unconformities and was misled by lithologic resemblances.

Igneous rocks occur sparingly in the Algonkian series. An intrusive sheet of diorite is extensive in the upper limestone formation and an extrusive flow of diabase caps it.

Carboniferous limestone, with an abundant fauna of the Saint Louis horizon, was found west of the Front ranges. Cretaceous strata underlie the Great Plains, and fossils of Dakota, Benton, and Laramie age were collected from them. Early Tertiary conditions are represented by erosion surfaces on the Great Plains, probably also in the Galton range, and possibly in the Front ranges. Later Tertiary lake and marsh deposits occur in the valley of North Fork of the Flathead. Preglacial gravel beds were distinguished at a high level above existing drainage channels. The drift is not discussed.

The Algonkian strata form a syncline whose axis trends west of north. Southwestern dips vary from 5 to 30 degrees. Northeastern dips are generally 30 to 40 degrees and locally approach or pass verticality. Minor flexures within the syncline are very broad and low. The northeastern limit of the fold is an eroded margin; the southwestern is an anticlinal axis whose western limb is in part eroded, in part thrown down by a normal fault along North Fork valley. Syncline and anticlines are closely related to valley and ridge respectively, and this relation extends to heights of peaks.

Along its eastern margin the oldest Algonkian formation rests upon Cretaceous rocks. The outcrop of this abnormal contact is deeply sinuous throughout the stretch from Saint Mary lake to Waterton lake. The structure is described as an overthrust fault, on which the Algonkian series has moved northeastward relatively over the Cretaceous rocks. The displacement on the thrust surface is 7 miles or more, and the vertical throw is estimated at 3,400 feet or more. The thrust surface dips from no degrees to ten southwestward and strikes variously from north to North 60° West. Thus it is warped, and this warping is found to determine the general outline of the eastern face of the Rocky mountains, particularly the prominence of Chief mountain, and the relative position of the Lewis range, *en echelon* to the Livingston.

Under the subject of structural antecedents the writer discusses hypothetical conditions from which the overthrust fault may have resulted. The physical history of the region is traced from the Dakota epoch to Miocene time. Observed facts are arranged in sequence, interpreted, and supplemented by inferences. Deposition, deformation, erosion to a peneplain, and later deformation are considered as successive stages in development of the present geologic and physiographic relations. It is concluded that the Lewis range owes its present elevation above the Great Plains largely to upward movement on the overthrust; that this uplift was preceded by a peneplain stage which came to a close in early or mid Tertiary, and that the elevation of the Front ranges dates from that time. Subsequently they were isolated along their western margin by normal faulting, which determined new drainage lines.

INTRODUCTION

During the summer of 1901 the writer visited that portion of northwest Montana lying west of longitude 113 degrees 30 minutes and north of latitude 48 degrees 30 minutes, and examined especially the stratigraphy and structure of that part of the Rocky mountains between the Great plains on the northeast and Flathead valley on the southwest. The district lies in Teton and Flathead counties, Montana, and in the adjoining divisions of British America. It comprises the Front ranges, which consist of two heights, the Lewis and Livingston crests. Streams flowing from it enter the Saskatchewan, the Missouri, and the Columbia, and it thus contains the main continental divide between the Atlantic and Pacific oceans, as well as that between Hudsons bay and the gulf of Mexico.

The purposes of the expedition were those of general reconnaissance. The work laid out for the season extended to an investigation of a strip 180 miles long, south of the international boundary, as far west as longitude 116 degrees 30 minutes, and therefore detailed work in any specific district was impracticable. Nevertheless, two months were passed in actual fieldwork in the Front ranges of the Rocky mountains, and sufficient data were gathered to add materially to our knowledge of them.

In this trip the writer was associated with Mr Stuart Weller, paleontologist, and Mr George I. Finlay, assistant geologist, and he is indebted

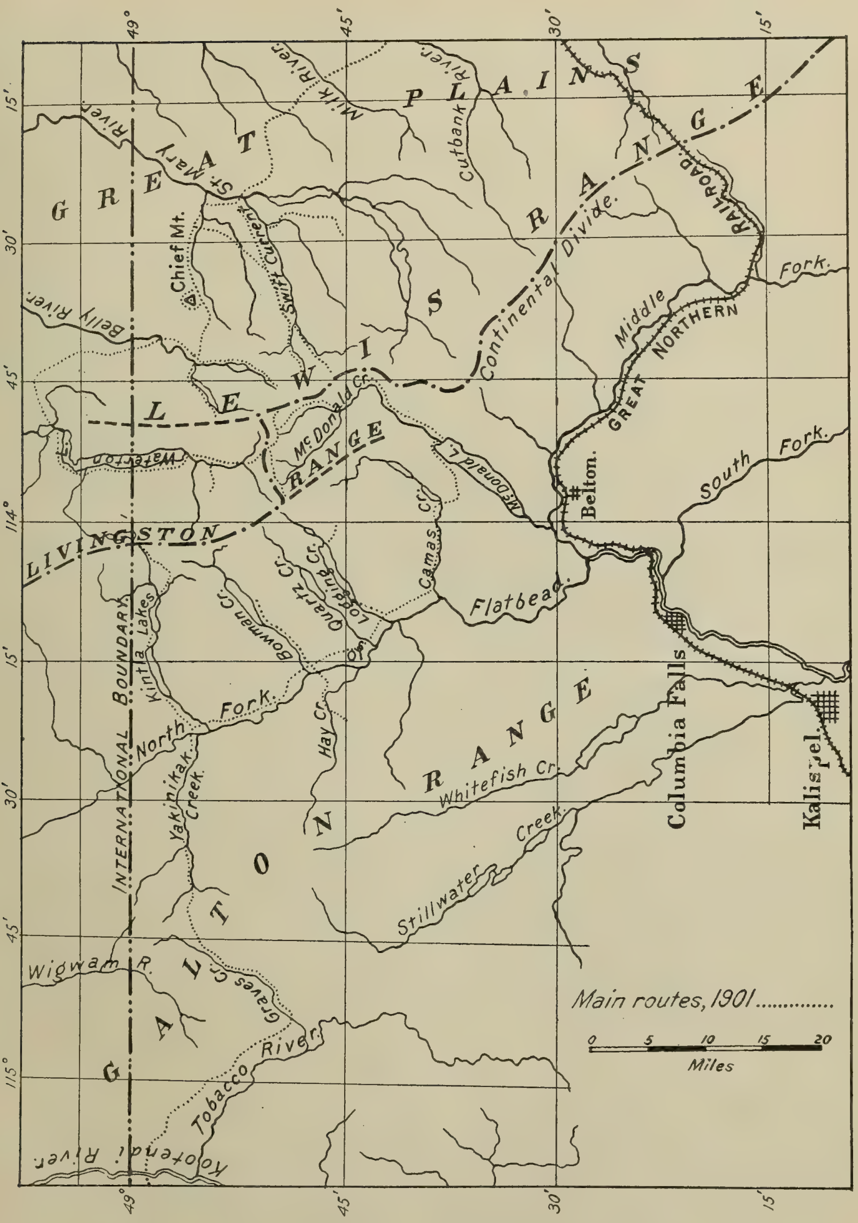
49°
45'
30'
15'
114°
115°
GREAT PLAINS
LEWIS RANGE
LIVINGSTON RANGE
GALTON RANGE
Continental Divide.
St. Mary River
Milk River
Cutbank River
Belly River
Chief Mt.
Swift Current
Waterton
McDonald Cr.
McDonald L.
Camas Cr.
Quartz Cr.
Logging Cr.
Bowman Cr.
Kintla Lakes
Hay Cr.
North Fork.
Middle Fork.
South Fork.
Flathead
Belton.
Columbia Falls
Kalispel.
GREAT NORTHERN RAILROAD.
Whitefish Cr.
Stillwater Creek
Yakinikak. Creek.
INTERNATIONAL BOUNDARY.
Wigwam R.
Graves Cr.
Tobacco River.
Kootenai River.
Main routes, 1901.............
0 5 10 15 20
Miles

FIGURE 1.—*Map of Northwest Montana.*

Showing Lewis and Livingston ranges and their relations to the Great Plains.

to both gentlemen for their cordial assistance. Mr Weller especially, through his persevering search for fossils, contributed to the definite results of the work. Mr Finlay's notes on igneous rocks are appended to this article.

Physical Features

GREAT PLAINS

The eastern portion of the area examined lies adjacent to the Rocky mountains, in the Great plains, which were traversed from Blackfoot, a station on the Great Northern railway, to the 49th parallel. Although properly described as part of the plains which stretch eastward for a thousand miles, the surface here has marked relief, there being differences of elevation which amount to 500 feet between summits and valleys. About Blackfoot and Browning the relief is partly built up by moraine of the great continental glacier, and along the eastern base of the mountains there are generally morainic accumulations from the local glaciers which descended along the valleys.* The greater part of the inequality of altitude is due, however, to the down cutting of the streams. These are consequent on the general slope descending northeasterly. The valleys, as a rule, are broad and defined by one, two, or more terraces, of which the lower ones were built up and cut down by the stream in recent times, but the higher ones are plains of erosion across marine strata.

The highest surfaces of the plains are limited in extent, constituting according to field estimate not more than one-fiftieth of the total area. Nevertheless, their profiles fall into a uniform line that represents an ancient plain, due to erosion across Cretaceous shales and sandstones of unequal hardness. The extent and uniformity of this plain are very marked, and it is the initial physiographic fact of the region. It is herewith designated the Blackfoot plain, after the Indian tribe whose name is associated with the region. On this ancient surface there is a widely distributed thin layer of gravel which is supposed to antedate the Pleistocene deposits.

FRONT RANGES

Lewis range.—The Front ranges of the northern Rockies between latitudes 48 degrees 40 minutes and 49 degrees 10 minutes present two parallel crests about 8 miles apart. The eastern one rises from the Plains in Canada about latitude 49 degrees 10 minutes between Saint Marys

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*See summary of observations of F. H. H. Calhoun, by R. D. Salisbury. Journal of Geology, University of Chicago, January, 1902.

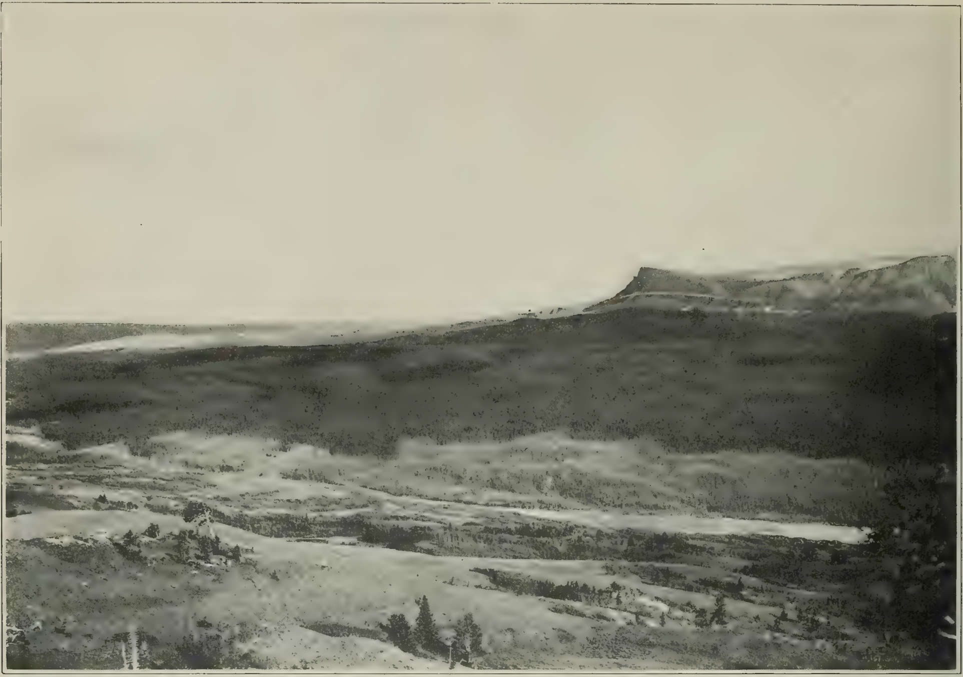


Figure 1.—Margin of Great Plains at Foot of Lewis Range

Looking south across Swift Current valley to Saint Mary ridge and East Flattop

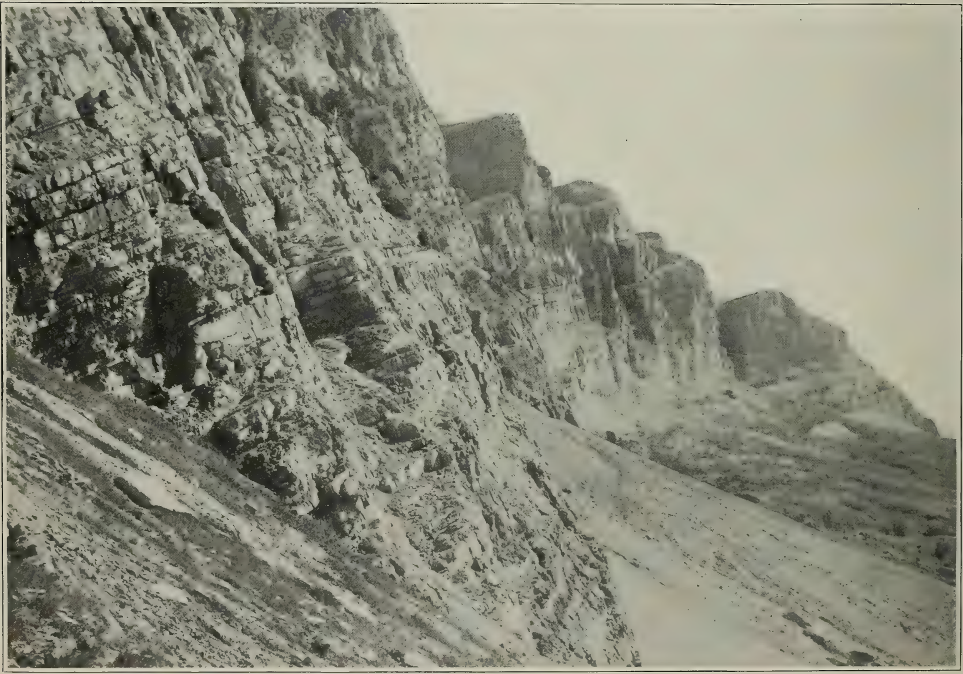


Figure 2.—North Side of Swift Current Valley near Altyn

Looking east. Typical Altyn limestone cliff, lower member, overlying Benton shale. Locality of Algonkian fossils

MARGIN OF GREAT PLAINS AND NORTH SIDE SWIFT CURRENT VALLEY and Waterton rivers, and extends southeastward to about latitude 46 degrees 45 minutes. It will be designated the Lewis range after Captain Meriwether Lewis, who in 1806 was the first white man to cross it. As the Lewis range does not extend far north of the 49th parallel, the western crest becomes in Canada the easternmost heights of the Rocky mountains, and it has there been called the Livingston range. This name is herein adopted and applied to the mountains as far south as mount Heavens near McDonald lake. Here the Livingston range appears to fall away and lose its identity. Between the Lewis and Livingston ranges is an elevated valley in which Waterton river and the tributaries of McDonald lake have their sources, the former flowing northerly, the latter southwesterly from a flat-topped mountain in the heart of the range.

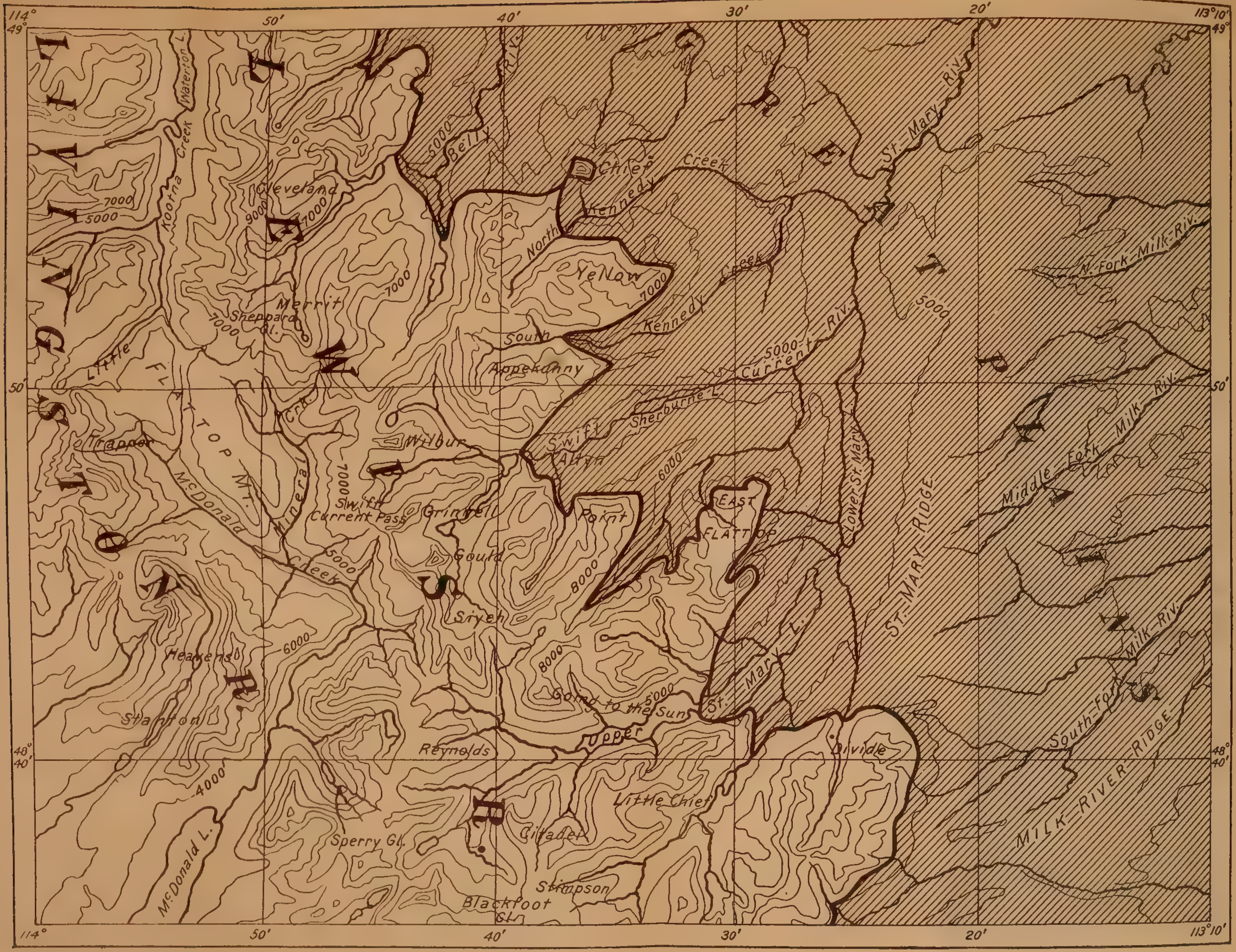
From the Great plains prominent spurs of Lewis range rise very boldly in the mountains known as Divide, Red Eagle, East Flattop, Yellow, and Chief, and in the heights west of Belly river. Looking at one of these promontories in profile it may be seen to present towards the northeast a bold and even precipitous scarp (figure 1, plate 47), from the foot of which the line of slope of the Great plains descends gently eastward. These mountain promontories carry the contours between 8,000 and 9,000 feet elevation as much as ten miles out to the northeastward from the main crest of the Lewis range. Between them are valleys excavated at elevations between 4,500 and 5,000 feet above the sea, which extend at moderate level very nearly to the crest of the range, and end in radiating canyons, under cliffs that rise boldly about their heads (see plate 46). They are also bounded along their sides by cliffs which outline the promontories (figure 2, plate 47). Thus the eastern margin of the Lewis range is deeply sinuous, and the heights above the general altitude of the Plains are marked off by cliffs from the lower slopes. The promontories are commonly sharp ridges of mature form, but are sometimes broad. That which lies between Boulder creek and Saint Mary lakes, and which is called East Flattop, carries a broad plateau-like summit at 7,000 to 8,000 feet above sea. This summit is unsympathetic to its environment and represents an older phase of topography. The slopes of the valleys exhibit soft and rounded forms, due either to erosion of incoherent clay shales, to deposition of glacial drift, or to numerous landslides.

The crest of the Lewis range is everywhere narrow, and in many places is a knife edge of jagged rocks. The precipices by which it is defined are frequently more than a thousand feet in height, and in some instances attain an altitude of 4,500 feet with a slope that is nowhere below 50 degrees. These cliffs are the walls of profound amphitheaters, usually occupied by lakes. The sculpture is that which is characteristic of the activity of valley glaciers in strongly jointed flat-bedded rocks. None of the high summits were ever submerged beneath a general ice-sheet, although glaciers accumulated to great depth in the valleys. The spurs which extend from the crest northeasterly have summit characters resembling those of the crest in its immediate vicinity and sometimes to a distance of several miles away from it.

Differences of elevation along the crest of the Lewis range are scarcely less pronounced than they are across it. Its rugged backbone is accentuated by high peaks between which are deep U-shaped wind gaps. The elevations of the highest summits range from 8,500 to 10,400, and those of the wind gaps from 5,500 to 6,500. Many small glaciers still linger in the shadows of the high peaks, and the Harrison and Blackfoot glaciers are nearly continuous for 5½ miles along the summit between Harrison creek and Saint Mary river.

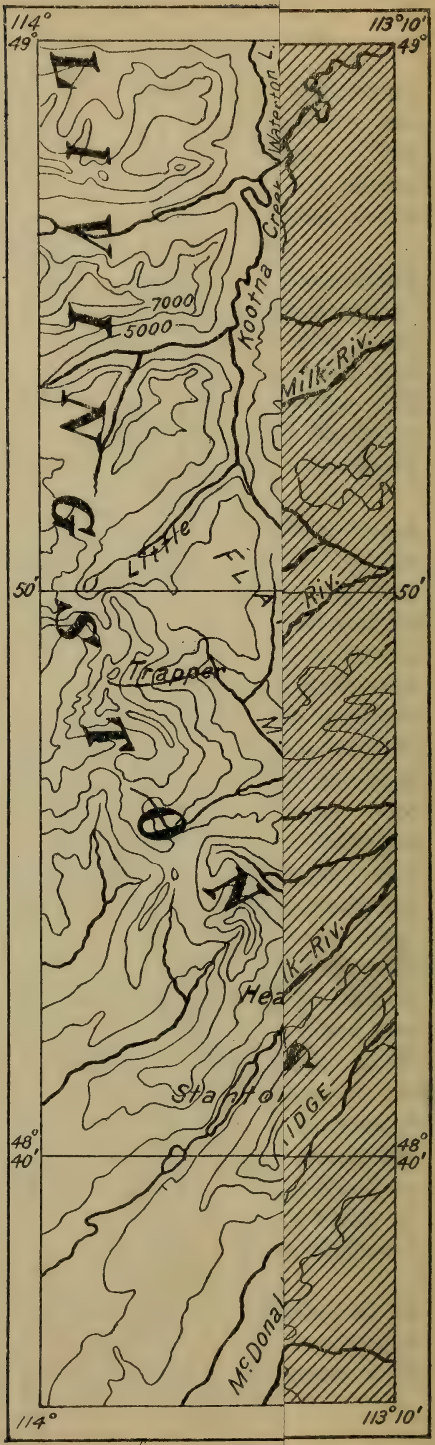
Waterton-McDonald valley.—West of the Lewis crest and between it and the Livingston crest lies the central valley of the Front range. It has the trend common to all the major features, north 10 to 20 degrees west, and is drained by two streams, one of which, Waterton river and its head tributaries, flows north, the other, the McDonald lake drainage, flowing south and southwesterly. The divide between these streams is known as Flattop mountain, but should not be confused with the Flattop mountain east of the Lewis range. It has an elevation of about 6,800 feet, and is a broad expanse of slight relief, which was in fact the floor of an older valley under a previous condition of drainage lines. The head of Waterton river, Little Kootna creek, lies in a canyon 3,000 feet deep, across the northern end of Flattop mountain, and Mineral and McDonald creeks, which unite to flow to McDonald lake, lie respectively on the northeast and southwest sides of the mountain, also in deep, steep-sided canyons (see figures 1 and 1, plates 50 and 51, in panorama). These canyons represent the latest work of the streams in engraving their channels on the old valley floor. Remnants of the higher and earlier valley extend as broad benches along the western slope of the Lewis crest and the eastern slope of the Livingston crest. Northwestward beyond Little Kootna creek and southeastward beyond the canyon of Mineral creek are high mountain masses which attain very nearly the extreme altitudes of the eastern and western crests. The exact relations of these several physiographic features, the date of the ancient valley of Flattop mountain, and its relation to one or more episodes of glacial occupation, are not yet fully made out.

Livingston range.—North of McDonald lake and surrounded at its eastern and southern base by McDonald creek is a conspicuous height known as mount Heavens. During much of the summer season it is


114°
50'
40'
30'
20'
113°10'
49°
50'
48°40'
LIVINGSTON
LEWIS
R.
GREAT PLAINS
Waterton L.
Kootna Creek
7000
5000
Cleveland
9000
7000
Belly Riv.
5000
Chief
Kennedy
North
Creek
St. Mary Riv.
N. Fork Milk Riv.
Yellow
Kennedy Creek
Merrit
Sheppard Gl.
South
Appekunny
Current Riv.
5000
Little
Flattop Mt.
Cra.
Wilbur
Swift
Altyn
Sherburne L.
6000
Trapper
McDonald Creek
Mineral
7000
Swift Current Pass
Grinnell
Point
East Flattop
Lower St. Mary
St. Mary Ridge
Middle Fork Milk Riv.
5000
Gould
8000
Siyeh
Heavens
6000
8000
Going to the Sun
5000
St. Mary L.
South Fork Milk Riv.
Stanton
Upper
Reynolds
Divide
Milk River Ridge
4000
Little Chief
Sperry Gl.
Citadel
McDonald L.
Stimpson
Blackfoot Gl.

MAP OF GREAT PLAINS AND FRONT RANGES, NORTHWEST MONTANA

Reduced from Browning and Chief Mountain atlas sheets, U. S. Geological Survey. Shaded area, Cretaceous rocks; white area, Algonkian rocks; heavy black line, outcrop of Lewis thrust. For section from Chief mountain to North Fork valley see plate 53.


114°
49°
113°10'
49°
LIVINGSTON
Waterton L.
Kootna Creek
7000
5000
Milk Riv.
Little
FL A
Riv.
50'
50'
Trapper
M
Hea
k Riv.
Sta fo
IDGE
48° 40'
48° 40'
McDonal
114°
113°10'

Reduced from Browning and Clction from Chief extensively mantled with snow and carries a small glacier on its northeastern slope. This is the southernmost peak of the Livingston range, from which the crest is extended northwestward to its limit, probably in mount Head, in British Columbia, about in latitude 50 degrees 25 min, utes. Like the Lewis crest, that of the Livingston range is often narrow-but of the two it is the wider, and it presents massive mountain groups, with pyramidal forms instead of knife-edge arêttes. Between these groups are deep U-shaped wind gaps, very similar to those which mark the Lewis range, and from them the descents are steep to the headwaters of streams flowing southwesterly.

The main continental divide from a point in British Columbia follows the Livingston range to latitude 48 degrees 50 minutes, not quite as far south as mount Heavens, then descends on to Flattop mountain between Little Kootna and McDonald creeks, and ascends to the Lewis range, which it follows about to latitude 46 degrees 45 minutes.

The western slope of the Livingston range is deeply sculptured by valleys which, descending from the wind gaps, contain long, narrow lake basins. Each one of the streams south of the 49th parallel—Kintla, Bowman, Quartz, Logging, Camas, and McDonald—spreads out into one or more lakes, which vary in length from 2 to 10 miles. Unlike the rock-bound pools which lie in the amphitheaters of Lewis range, these waters are margined chiefly by slopes of gravel or talus, and only about their upper ends do the mountains rise with anything approaching a precipitous character. The shores and slopes are forest-clad, giving them an aspect very different from that of the valleys on the northeastern side of the mountains.

Although the mass of the Livingston range is thus deeply sculptured, the limit of the mountains on the west is definite, and, unlike the sinuous margin of the Lewis range toward the Great plains, it has the character of a bold face rising from foothills.

FLATHEAD VALLEY

West of the Livingston range in the United States and southern British Columbia extends the valley of the North fork of Flathead river. It is a broad depression with a general altitude along the river course from 3,100 feet near the forks of the Flathead to 3,500 feet about the 49th parallel. The river is a swift, clear stream, sometimes 50 yards wide, with many gravelly bars and deep pools. It winds in numerous oxbows, now between low gravel banks of its flood plain, again past higher terraces of drift, and occasionally under bluffs of stratified clays, with which sandstones and lignites are interbedded. The wide valley opens back from the channel of the stream to a distance of from 2 to 5 miles with an ascent by terraces and irregular slopes to foothills of the Livingston range on the east. The drift deposits extend above an elevation of 5,000 feet, and about that level present east and west profiles of a flat character, suggesting that the deeper part of the valley was once occupied by ice or gravel, and the space between it and the mountains was filled to a comparatively smooth surface.

The presence of the drift at so great an elevation carries the profile from the valley to the rocky heights of the Livingston range with a much gentler grade than would be the fact were the drift removed. It appeared from a brief examination of Camas, Logging, Bowman, and Kintla lakes that the face against which the drift is piled was limited along a line extending across the several valleys from southeast to northwest after the fashion of a definite scarp, and upon this apparent fact in part is based an inference as to the structural relation of the Flathead valley and the Livingston range.

STRATIGRAPHY

GENERAL STATEMENT

The strata encountered in that part of the Front range of the northern Rockies to which this article refers belong to five great periods of geologic history, separated by immense gaps. The oldest are sediments of pre-Cambrian age, in large part at least, with possibly some early Cambrian strata. They have an aggregate thickness of more than 12,500 feet. Carboniferous limestone was observed in a small area in the Galton range west of Flathead valley, on Yakinikak creek, and although it is absent from the Front range near the 49th parallel, it occurs to the northwest and southeast as well as west, and probably extended over the entire range. Strata of Cretaceous age occur extensively in the Great plains and in the valleys which penetrate so deeply into the eastern slope of the Lewis range. Lake beds of Tertiary age, either of Miocene or Pliocene date, are exposed in the bluffs along the North fork of Flathead river. East of the Front range on the foothills of the great promontories overlooking the Plains, and on the highest levels of the Great plains themselves, there are coarse gravel deposits of stream-worn material, which apparently antedate any glacial formations of the region, and may be Pliocene or early Pleistocene. Finally, the latest episodes of development are recorded in glacial drift, partly brought down from the valleys and partly deposited by the great continental glacier which spread from the northeast over the Plains toward the base of the Rockies. Closely related to all of that portion of the history which is of post-

Cretaceous age is the physiography of the range, a record that must be read in connection with the deposits from lakes and glaciers and should be interpreted in the light also of the structural geology.

The following is a tabular statement of these rocks and of the formations into which they are classified for the purposes of this report:

Geologic Formations represented

Pleistocene.	Eastern continental drift.	Characterized by boulders of granitic, gneissoid, and other Laurentide rocks; forms a moraine across Saint Mary and Belly valleys and beyond.
	Valley glacier drift.	Distinguished by absence of Laurentide rocks; composed of Algonkian sedimentary and igneous rocks in heterogeneous association as till and stratified drift.
Pleistocene or Pliocene.	Kennedy high level gravels.	Type locality—a gravel mesa, elevation 5,800 feet, 5 miles east of Chief mountain, north of Kennedy creek, and 900 feet above it; characterized by waterworn material of local origin, Algonkian rocks up to 2 feet in diameter; average coarse stuff under 1 foot, much of it 2 to 6 inches; distinguished by absence of glacial striæ, by stratification, and by altitude above present stream channels (figure 2, plate 51).
Later Tertiary.	Lake beds and marsh deposits of North Fork valley.	Clay, stratified, light gray; fine, very homogeneous; interbedded with very friable, light greenish sands and brown lignite.
Earlier Tertiary.	Blackfoot peneplain.	Highest and oldest peneplain of the Great plains in this district, cut across upturned Laramie and older strata.
Cretaceous.	Laramie sandstone.	Sandstone, hard, gray, cross-bedded, and soft shaly interbedded, carrying layers of oyster shells and containing plant remains.
	Benton shale.	Shale, dark, bluish gray, very fissile, fossiliferous, with occasional beds of sandstone, medium grained, brown, and thin limestone layers.
	Dakota sandstone.	Sandstone, yellow and brownish, and shale, arenaceous, with plant remains and freshwater shells.

Carboniferous	Yakinikak limestone.	Limestone, light gray to dark gray blue, crystalline, specked with black cleavage faces, or amorphous; sometimes oölitic; weathers rough; highly fossiliferous, Saint Louis horizon; type on Yakinikak creek, 4 miles west of North fork of Flathead river.
	Quartzite.	Quartzite, massive, coarse, white, or iron-stained; weathers into rounded bosses; 25 feet thick between conformable limestone above and unconformable argillite below.
Algonkian.	Kintla argillite.	Argillite and quartzite, thin-bedded, maroon red, ripple-marked, and sun-cracked, containing casts of salt crystals; also occasional beds of white quartzite and some calcareous; thickness, 800 feet; no upper limit seen; type locality, pyramidal peaks on 49th parallel, at head of Kintla drainage, foreground of figure 2, plate 50.
	Sheppard quartzite.	Quartzite, yellow, ferruginous; thickness, 700 feet ±; overlies extrusive diabase flow; type locality, cliffs between head of Belly river and central Flattop mountain.
	Siyeh limestone.	Limestone chiefly, but with argillite interbedded, usually massive, of mural aspect (plate 49), dark blue or grayish, weathering buff; often characterized by peculiar internal structures and by large concentric growths; indistinctly fossiliferous, associated with an intrusive diorite sheet and dikes and with an extrusive diabase flow at its upper surface; thickness, 4,000 feet; type locality, mount Siyeh, at head of Canyon creek, Swift Current drainage, but equally well exposed in other high peaks (plate 46), mount Gould.
	Grinnell argillite.	Argillite, dark red, shaly, sometimes arenaceous, ripple-marked, and sun-cracked; thickness, 1,000 to 1,800 feet; type locality, mount Grinnell, at head of Swift Current valley; also well exposed in Appekunny and Robertson mountains.
	Appekunny argillite.	Argillite, prevailingly gray, black, and greenish; thin-bedded, ripple-marked, interbedded with white quartzite; carries flattened concretions resembling fossils; thickness, 2,000 feet ±; type locality, Appekunny mountain, north of Swift Current valley; also generally well exposed in Lewis and Livingston ranges.

Algonkian.	Altyn limestone.	Limestone, of which two members are distinguished; an upper member of argillaceous, ferruginous limestone, yellow, terra-cotta, brown, and garnet red, very thin-bedded; thickness, about 600 feet; well exposed in summit of Chief mountain (figure 1, plate 52); and a lower member of massive limestone, grayish blue, heavy-bedded, somewhat silicious, with many flattened concretions, rarely but definitely fossiliferous; thickness, about 800 feet; type locality, basal cliffs of Appekunny mountains, north of Altyn, Swift Current valley (figure 2, plate 47).

ALGONKIAN

Correlation.—The oldest rocks found in this district are those which constitute the Lewis and Livingston ranges. The oldest formation of the series, the Altyn limestone, is assigned to the Algonkian period on the basis of fossils discovered by Weller in its characteristic occurrence at the foot of Appekunny mountain near Altyn, Montana. These fossils are fragments of very thin shells of crustaceans. They have been examined by Walcott, who states:

> "The fragments of crustaceans collected by Professor Stuart Weller, in Montana, may be referred provisionally to *Beltina danai*, as described in volume X, page 338, of the Bulletin of the Geological Society of America.
>
> "The mode of occurrence of the material is similar to that found in the Grayson shales of the Algonkian in the Belt mountains, Montana. Hundreds of broken fragments of the carapace of the crustaceans are distributed unevenly through the rock. Occasionally a segment or fragment of what appears to be one of the appendages is sufficiently well preserved to identify it."

The fossiliferous strata of the Belt formation in the Belt range are separated from the Cambrian by 7,700 feet of sediments and an extensive unconformity. In the Front range of the Rockies 10,700 feet of apparently conformable strata overlie the fossiliferous bed, and it is possible that the plane of division between Algonkian and Cambrian as determined by paleontologic evidence will be found in this great series. In the upper part of the Siyeh limestone near the head of Mineral creek, Weller found some indistinct forms which he considers possibly to be parts of crustaceans. Walcott expresses a similar view, saying:

> "Mr Weller's suggestion that the fragments possibly represent crustacean remains appears to be the most plausible. If from a Devonian horizon they would suggest the genus *Licas*, or some of its subgenera. It is a case where more material is needed in order to arrive at any definite conclusion."

In the upper part of the Siyeh limestone there are also large concretionary masses which are irregularly cylindrical in form, with major axes at right angles to the bedding of the rocks, and which attain the dimensions of a keg, and even of a small barrel. Walcott states that these forms are similar to those found in the pre-Cambrian rocks north of Helena, Montana, but as yet they have yielded no evidence of organic origin. "Sir William Dawson considered that they represented a very simple form allied to Stromatopera."

In the British Boundary Commission report* Dr George M. Dawson describes these ancient rocks under the caption "Review of the Section," as follows: †

"The total thickness of the beds seen in this part of the Rocky mountains must be about 4,500 feet, though this can only be regarded as an approximation, as, owing to the short time at my disposal, few of the beds were actually measured. The entire series, arranged as a continuous section in descending order, is as follows:

H. Fawn-colored flaggy beds, seen only at a distance, but probably composed of magnesian sandstones and limestones. 100 feet.

G (Kintla formation). Beds characterized by a predominant red color and chiefly red sandstone, but including some thin, grayish beds, and magnesian sandstones, the whole generally thin-bedded, though sometimes rather massive. Ripple marks, &c. Weathers to a steep rocky talus where exposed in the mountain sides, and passes gradually down into the next series. 300 feet.

F (Sheppard quartzite). Fawn-colored flaggy beds of magnesian sandstone and limestone. Some red sandstones occur throughout, but are especially abundant toward the top. Apparently a continuation upward of the limestone D, and only separated from it by the trap overflow. 200 feet.

E Amygdaloidal trap; dark colored and hard. 50 to 100 feet.

D (Siyeh limestone). Compact bluish limestone, somewhat magnesian, and weathering brownish. This forms some of the boldest crags and peaks of the mountains, and apparently rests unconformably on Series C. 1,000 feet.

C (Grinnell and Appekunny formations). Sandstones, quartzites, and slaty rocks, of various tints, but chiefly reddish and greenish gray; the individual beds seldom of great thickness, and the color and texture of approximate beds rapidly alternating. In this series occurs a band of bright red rocks, of inconstant thickness; also two or more zones of coarse magnesian grit. 2,000 feet or more.

B (Uppermost bed of Altyn limestone). Limestone, pale gray, cherty, and highly magnesian; hard, much altered, and weathering white. It includes at least one band of coarse magnesian grit like that found in the last series, which weathers brown. 200 feet.

A (Altyn limestone, upper part). Impure dolomite and fine dolomitic quartzites; dark purplish and gray, but weathering bright brown of various shades. 700 feet or more."

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*George M. Dawson: British Boundary Commission Report on the Geology and Resources of the Region in the Vicinity of the Forty-ninth Parallel, 1875, pp. 67, 68, and Canada Geological Survey Report, 1885, p. 39 B et seq.

†The names used in this report are inserted in brackets after the letter by which Dawson designated the corresponding beds.

As regards thickness of the above described section, Dawson's figures sum up 4,500 feet. Elsewhere* he says:

> "Between the eastern summit of the South Kootanie pass and the Flathead river, the minimum estimated thickness of the outcropping Cambrian beds is 11,000 feet, but the section includes neither the summit nor the base of the series. Other sections show a probable thickness of over 5,000 feet for a part of the series, but none were found in which its whole volume could be ascertained."

The writer's measure of the series which Dawson called Cambrian, namely, the Altyn, Appekunny, and Grinnell formations, is 6,700 feet, but, adding the Siyeh, Sheppard, and Kintla formations, is 10,700 feet, which is an approximation to his estimate of 11,000. The latter three formations occur in the section to which Dawson refers, and though he elsewhere classed them as Carboniferous and Triassic, they are part of the thickness which, in the quoted paragraph, he includes under Cambrian.

Dawson notes an apparent unconformity between D (the Siyeh limestone) and C (the Grinnell red beds) He says: †

> "In the almost vertical side of Sheep mountain the total exposed thickness of beds of series C must be about 2,000 feet. These rest directly on the limestone B, and are overlain by the limestone series D, the latter resting with evident unconformity on them. This unconformity is shown very clearly by the existence of a thick belt of bright red rocks, forming part of series C, which is observed to run out altogether beneath the upper formation at one end of the mountain."

The writer also observed this relation, but he interprets it as due to a minor thrust rising from the Lewis major thrust which underlies Sheep mountain. The structure was identical in appearance and position with others seen traversing the Altyn formation in Yellow mountain (figure 6, page 335). It is also exceptional in the relations of division C to D, which were observed throughout many miles as the conformable contact of the Siyeh limestone on the Grinnell argillite.

About the outlet of Waterton lake, the Cretaceous rocks are deeply buried by drift and the outcrop of the Lewis thrust is obscured. The unusual superposition of the ancient argillites and limestones on the Cretaceous might well escape even so keen an observer as Dawson. He did not visit Chief mountain or any other locality where the evidence is clear.

In 1875 Dawson assigned no definite age to the rocks in question. In 1885, after more extended experience in the Canadian Rockies, he provisionally classified them as follows:

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* Canada Geological Survey, Report 1885, p. 158 B.

† Canada Geological Survey, Report 1885, p. 41 B.

Probably Triassic or Permo-Triassic	Divisions F, G, and H.
Carboniferous and Devonian	Division D.
Cambrian	Divisions A, B, and C.

The correlation appears to have been made on lithologic resemblances and the existence of the supposed unconformity between the red argillite C and the limestone D. A, B, and C are now known to be Algonkian, on fossil evidence. Mention is made by Dawson of the absence of fossils from C, but nothing is said about their occurrence or non-occurrence in D. Weller's careful search in the Siyeh limestone (D) showed the presence of indistinct remains, as already noted, but it also proved that fossils are rare and obscure in the formation. If the rock is of Carboniferous age, it is remarkable that it should not contain some of the larger characteristic forms, as the Carboniferous limestone on Yakinikak creek, but 26 miles distant, carries an abundant fauna. There is no metamorphic or structural condition affecting the one rather than the other in a degree sufficient to explain the difference in faunal content. Moreover, the Carboniferous limestone on Yakinikak creek rests unconformably on beds of the series of which the Siyeh limestone (D) is apparently a conformable formation.

The writer concludes that the Siyeh limestone is not of Carboniferous age, and that there is no evidence to justify its being separated from the underlying Algonkian, to which it is conformable and with which it is related in the obscure character of its fossils. This conclusion applies also to the Sheppard and Kintla formations, which Dawson placed in the Permo-Triassic. He could not otherwise refer them, conceiving them to overlie the Carboniferous, as they have strong Triassic characters; but with the assignment of the Siyeh limestone to the Algonkian, they also take a related place in that system. Nevertheless, to give full expression to Dawson's views, the following paragraphs are quoted from his report:*

> "South of the line of the Crow Nest pass, the limestone series (Carboniferous) is conformably overlain by rocks which are referred to the Triassic or Permo-Triassic. In the vicinity of the South Kootanie pass, an interbedded, amygdaloidal diabase everywhere occurs at the base of the Triassic rocks. This, though classified under a separate letter (E) in the general section of that region (p. 39 B), is now known from the occurrence of a similar bed (if not the extension of the same one) among the distinctively Triassic rocks of the summit of the North Kootanie pass (p. 60 B) to be more properly ranked as a member of that series. The trap flow has a thickness of fifty to one hundred feet, and is overlain near the South Kootanie pass by red beds and fawn-colored magnesian sandstones 600 feet in thickness. Near the North Kootanie summit it forms part of a similar series

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*Canada Geological Survey, Report 1885, p. 161.

of alternating, flaggy, magnesian sandstones and red sandstones and shales 2,000 feet in thickness (p. 60 B). In connection with the red beds, ripple-marked surfaces, mud cracks, and impressions of salt crystals occur, the whole indicating, as the conditions of deposition of the rocks, those of a basin cut off from the main ocean.

"With the single doubtful exception of certain red beds, seen from a distance, near the summit of the White Man's pass (p. 115 B), these Triassic rocks are entirely confined to the district south of the Crow Nest pass, and, as elsewhere more fully shown, we find here probably the northern limit of a great Triassic mediterranean sea, which extended far to the southward in the western part of the present continental area."

Altyn limestone.—The lowest member seen of the Algonkian strata is a limestone. Its unweathered surfaces are dark grayish blue, and in lithologic aspect it closely resembles Cambro-Silurian dolomites of the Appalachian region and the massive limestone of the Eo-Carboniferous. It is silicious, but there are no visible quartz grains or other evidences of marked mechanical sedimentation. Its stratification is often obscure, partly on account of its massive character and even more because of very decided deformation, which has resulted in faulting and crushing. Its thickness is undeterminable, but probably not less than 800 feet. Succeeding this basal member and included with it in the Altyn formation are limestones which differ chiefly in that they contain more earthy sediment and are very thinly bedded. In consequence of the ferruginous clay contained, they are decidedly yellow, brown, and terra-cotta in color. They are sometimes separated from the underlying massive limestone by a plane, above which they lie flat, while the mass below is greatly disturbed (see figure 5, page 334). The effect strongly suggests an unconformable relation between the two, but this is not believed to have been the original condition of deposition as they were seen in conformity, where not traversed by thrust faults. The thickness of the thin-bedded upper member of the Altyn limestone is approximately 600 feet.

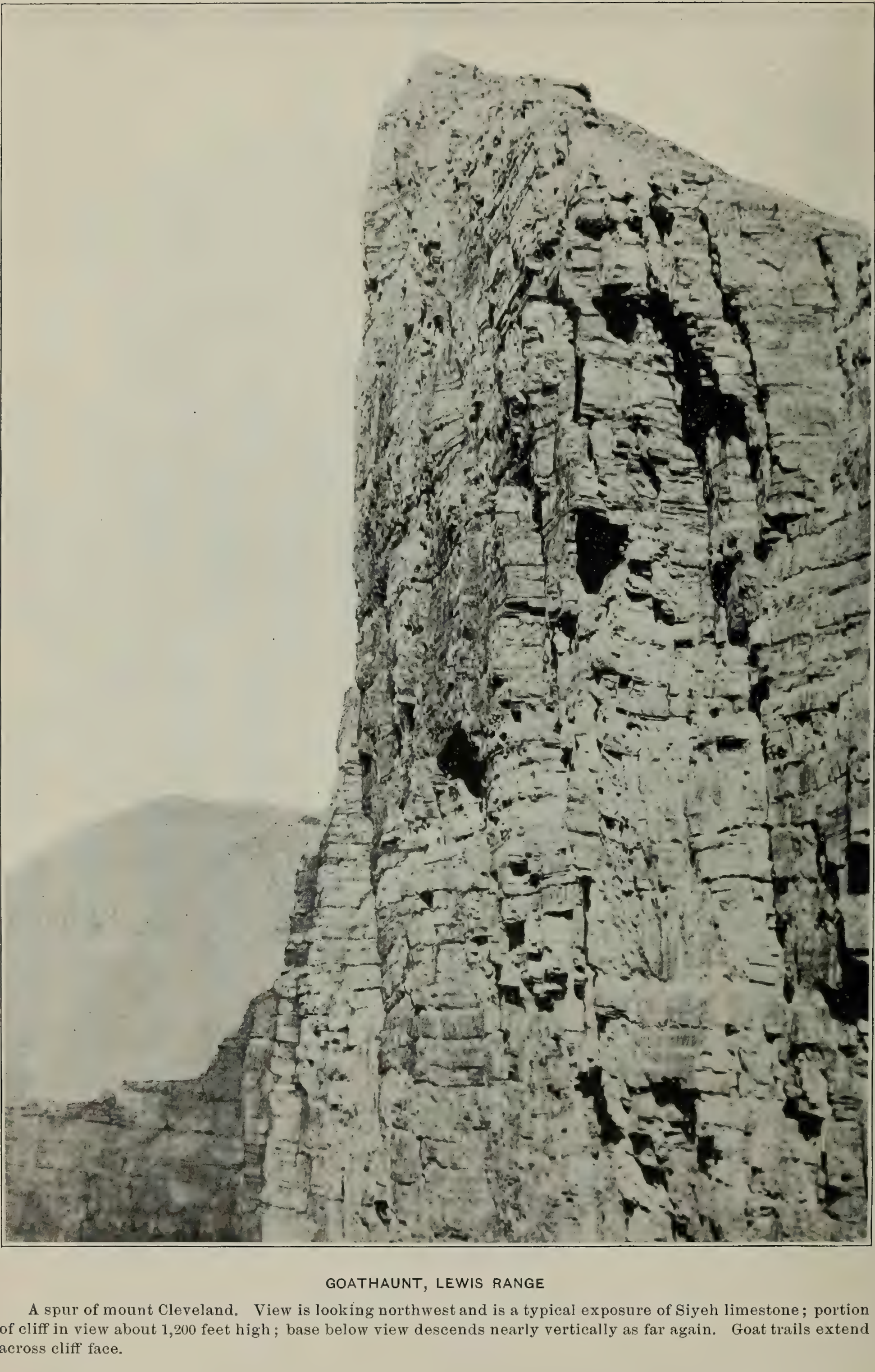
The Altyn limestone occurs typically in the cliffs of Appekunny mountain, between 6,000 and 7,400 feet above sea, due north of Altyn, in Swift Current valley (figure 2, plate 47). The westward dip carries the base down to about 4,800 feet west of Altyn, where it forms the ledge over which Swift Current falls at the outlet of McDermott lake. Northward and eastward from this locality the limestone forms the cliffs that surround Appekunny, constitutes the mass of Yellow mountain, the northern slopes of mount Robertson, and the ridge between Kennedy creek and Belly river, ending in the tower-like peak of Chief mountain. Beyond the forks of Belly river it was traced northwest into Canada and to the narrows of Waterton lake, whence the outcrop trends northward in the base of the Livingston range. Southeastward from Altyn the limestone was traced around Point and eastern Flattop mountains to the Narrows of upper Saint Mary lake. Thence it forms the base of the mountains southward to an unknown distance, but it may be replaced by any of the overlying formations, among which it is closely resembled by the Siyeh and Carboniferous limestones.

Appekunny argillite.—The Appekunny argillite is a mass of highly silicious argillaceous sediment approximately 2,000 feet in thickness. Being in general of a dark-gray color, it is very distinct between the yellow limestones below and the red argillites above. The mass is very thin bedded, the layers varying from a quarter of an inch to two feet in thickness. Variation is frequent from greenish-black argillaceous beds to those which are reddish and whitish. There are several definite horizons of whitish quartzite from 15 to 20 feet thick. The strata are frequently ripple-marked, and occasionally coarse-grained, but nowhere conglomeratic. An excellent section of these gray beds is exposed in the northeastern spur of Appekunny mountain, from which the name is taken, but the strata are so generally bared in the cliffs throughout the Lewis and Livingston ranges that they may be examined with equal advantage almost anywhere in the mountains.

The Appekunny argellite occurs everywhere above the Altyn limestone along the eastern front of the Lewis range from Saint Mary lakes to Waterton lake and beyond both northward and southward. It also appears at the western base of the Livingston range above Flathead valley and is there the lowest member of the series seen from Kintla lakes southward to McDonald lake.

Grinnell argillite.—A mass of red rocks of predominantly shaly argillaceous character is termed the Grinnell argillite from its characteristic occurrence with a thickness of about 1,800 feet in mount Grinnell. These beds are generally ripple-marked, exhibit mud cracks and the irregular surfaces of shallow water deposits. They appear to vary considerably in thickness, the maximum measurement having been obtained in the typical locality, while elsewhere to the north and northwest not more than 1,000 feet were found. It is possible that more detailed stratigraphic study may develop the fact that the Grinnell and Appekunny argillites are really phases of one great formation, and that the line of distinction between them is one diagonal to the stratification. The physical characters of the rocks closely resemble those of the Chemung and Catskill of New York, and it is desirable initially to recognize the possibility of their having similar interrelations.

The Grinnell argillite outcrops continuously along the eastern side of Lewis range and its spurs, occurring above the Appekunny argillite and



GOATHAUNT, LEWIS RANGE

A spur of mount Cleveland. View is looking northwest and is a typical exposure of Siyeh limestone; portion of cliff in view about 1,200 feet high; base below view descends nearly vertically as far again. Goat trails extend across cliff face.

dipping under the crest of the range at the heads of the great amphitheaters tributary to Swift Current valley. About the sources of the Kennedy creeks it forms the ridge which divides them from Belly river. Mount Robertson is a characteristic pyramidal summit composed of these red argillites. The formation occurs in its proper stratigraphic position between the forks of Belly river and west of that stream in the Mount Wilson range of the Canadian geologists, the northernmost extremity of the Lewis range; and it dips westward under the valley of Little Kootna creek and Waterton lake. On the western side of Livingston range the Grinnell argillite was recognized as a more silicious, less conspicuously red or shaly division of the system, occurring about upper Kintla lake.

Siyeh limestone.—Next above the Grinnell argillite is a conspicuous formation, the Siyeh limestone, which rests upon the red shales with a sharp plane of distinction, but apparently conformably. The Siyeh is in general an exceedingly massive limestone, heavily bedded in courses 2 to 6 feet thick like masonry (see plate 49). Occasionally it assumes slabby forms and contains argillaceous layers. It is dark blue or grayish, weathering buff, and is so jointed as to develop large rectangular blocks and cliffs of extraordinary height and steepness. Its thickness, as determined in the nearly vertical cliff of mount Siyeh, is about 4,000 feet.

This limestone offers certain phases of internal structure which may be interpreted as results of conditions of sedimentation or as effects of much later deformation. Some layers exhibit calcareous parts separated by thin argillaceous bands, which wind up and down across the general bedding and along it in a manner suggestive of the architectural ornament known as a fret. It is conceived that the effect might be due to concretionary growths in the limestone, either during or after deposition, or to horizontal compression of the stratum in which the forms occur. Other strata consist of fragments of calcareous rock from minute bits up to a few inches in diameter, but always thin, constituting a breccia in a crystalline limy cement. Again, other strata consist of alternating flattish masses of calcareous and ferruginous composition, which rest one upon another like cards inclined at angles of 30 to 45 degrees to the major bedding. At times the lamination is so minute as to yield a kind of limestone schist. These internal structures suggest much compression, but the apparent effects are limited by undisturbed bedding planes, and it is possible that the peculiarities are due to development of concretions and to breaking up of a superficial hard layer on the limestone ooze during deposition of the beds. Walcott has described similar structures as intraformational conglomerates.

The Siyeh limestone forms the mass of mount Siyeh, at the head of Canyon creek, a tributary which enters Swift Current at Altyn from the south. It constitutes the upper part of all the principal summits of Lewis range north of mount Siyeh, including mounts Gould, Wilbur, Merritt, and Cleveland. It extends beyond Waterton lake westward into the Livington range and forms the massive peaks between Waterton and North Fork drainage lines. Above upper Kintla lake it is sculptured in the splendid heights of Kintla peak and the Boundary mountains.

An exceedingly characteristic and general feature of the Siyeh limestone is the occurrence of an intrusive sheet of diorite, which is found throughout the area examined, with an approximately uniform thickness of 60 to 100 feet. The dikes by which this sheet was fed traversed the formation, following the vertical joint planes with offsets. The conditions of intrusion appear to have been extraordinarily uniform. The rock is described in more detail in the accompanying note by Mr Finlay:

The top of the Siyeh limestone, considered as a lithologic formation over that part of the area where it was observed, coincides with an extrusive igneous sheet, which was clearly erupted prior to the deposition of the succeeding strata, and exhibits the ropy flow structures incident to flow and cooling at the surface. The rock is of a rhyolitic nature.

Sheppard quartzite.—A distinctly sandy phase of deposition succeeding the extrusive rhyolitic eruption has resulted in a quartzite which is very roughly estimated to have a thickness of 700 feet. It forms the crest of Lewis range in the vicinity of mount Cleveland and Sheppard glacier between Belly river and Flattop mountain. It has not been studied in detail, but is recognized as a distinct division of the series.

Kintla argillite.—The highest beds of the ancient sequence of strata found in this part of the range are deep red argillaceous quartzites and silicious shales, with marked white quartzites and occasional calcareous beds. They are named the Kintla formation from their occurrence in mountains on the 49th parallel, northeast of Upper Kintla lake. They also form conspicuous peaks west of Little Kootna creek. The Kintla formation closely resembles the Grinnell, and represents a recurrence of conditions favorable to deposition of extremely muddy, ferruginous sediment. The presence of casts of salt crystals is apparently significant of aridity, as the red character is of subaerial oxidation. The formation has an observed thickness of 800 feet, but no overlying rocks were found. Its total thickness is not known, and the series remains incomplete.

CARBONIFEROUS—YAKINIKAK LIMESTONE

It having been determined by the work of McConnell and Dawson to the north and by that of Weed and Walcott to the south that the main range of the Rockies carries a great thickness of Carboniferous limestone, it was assumed that strata of that age would be found in the section near the 49th parallel, but in the Lewis and Livingston ranges nothing which could be referred to the Carboniferous system was observed. Dawson's correlation of the Siyeh limestone as Carboniferous has already been discussed. On crossing the Flathead valley, however, to the Galton range, which lies between North fork of the Flathead and Kootenai rivers, a small area of limestone was encountered in Yakinikak valley. The rock is a light gray and dark blue limestone about 100 feet thick, distinctly bedded, commonly crystalline, occasionally oolitic. Some fractures have a black, speckled appearance due to dark cleavage faces on calcite crystals. It is without upper stratigraphic limit, but rests conformably on a quartzite, which is unconformable on Algonkian strata. The quartzite is about 25 feet thick, and it and the limestone lie in a nearly horizontal position. The name Yakinikak is here applied to the limestone, exclusive of the quartzite, which may elsewhere develop independent importance.

The Yakinikak limestone contains numerous fossils of the Saint Louis horizon of the Mississippian series, and was fully identified by Weller as identical in lithologic character and faunal content with that formation in the Mississippi valley. Its occurrence on Yakinikak creek is apparently due to down-faulting, as it lies at a comparatively low level among mountains composed of the Algonkian argillites. Its presence in this locality, taken in connection with other occurrences north and south, may be considered evidence of the former extension of the upper Mississippian limestone over the entire region. The absence of the earlier Mississippian strata is significant of an unusual overlap.

In the course of a report of explorations in 1901* for coal on Wigwam river Mr W. W. Leach, of the Canadian Survey, refers to the "Devono-Carboniferous limestones of the MacDonald range, a high and extremely rugged group of mountains which forms the divide between Wigwam and Flathead rivers." The Yakinikak limestone lies at the southern extremity of the MacDonald range, which may be said to die out at the 49th parallel, and it is probable that its fossiliferous strata make up the heights farther north. It is also possible that it rests on Siyeh limestone, in which case the break between the two would not be readily recognized, as the rocks are very similar and the angular difference of dip is slight.

TRIASSIC

Dawson's report for 1885 and the accompanying map represent certain rocks of the Livingston range near the South Kootanie pass as Triassic. The validity of the correlation has been discussed. The evidence indicates that the strata are probably Algonkian.

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*Summary Report, Geological Survey Department of Canada, 1901, p. 72.

CRETACEOUS

General note.—Cretaceous strata are but poorly exposed along the eastern base of Lewis range, although they form the subterrane beneath hundreds of square miles of the plains. The mantle of drift is widespread and often thick, and outcrops of rock in place are limited to occasional freshly scoured gullies or ledges of sandstone along hilltops. Such outcrops were noted, however, in traversing the plains from Cutbank river to Saint Mary lake, and others were found about the mountain slopes west of Saint Mary lakes, up Swift Current valley, on Kennedy creek, about Chief mountain, and on Belly river. Weller collected fossils sufficient to determine three horizons, namely, Dakota, Benton, and Laramie, and through the light thrown by fossils on their relations these occasional Cretaceous outcrops become interesting as elements of a structure which they do not suffice to make clear. Their distribution is such that the Dakota and Benton, while occupying normal relations one to another, are apparently above the Laramie. The significance of this from the point of view of structure is discussed under that head.

No occurrences of rocks of Cretaceous age were observed west of the Front range of the Rockies, and it is probable that there are none south of the Crow Nest coalfields.

Dakota.—Arenaceous and argillaceous shales and sandstones of Dakota age occur on North fork of Kennedy creek near its junction with South fork, 5½ miles east by south from Chief mountain, at an elevation of 4,800 feet. The exposures constitute a bluff 30 feet high, near the top of which are layers bearing fossil plants and freshwater shells. A collection of leaves, though badly broken up in transit, was examined by Mr Knowlton, who reports *Ficus proteoides ?* Lesq., *Magnolia boulayana* Lesq., *Liquidamba integrifolius* Lesq., *Liquidamba obtusilobatum* Lesq. *Diospyro rotundifolia* Lesq., *Phyllites rhomboideus* Lesq. "The above species, says Knowlton, "are all characteristic Dakota Group forms, and the beds at this locality are referred without hesitation to this age." The strike of these Dakota strata is nearly north and south and they dip at a low angle, 0–10 degrees, westward.

Benton.—Dark bluish black to leaden gray shales constitute the mass of Cretaceous rocks west of Saint Mary lakes. With them are associated thin beds of limestone and ferruginous sandstone. Weller's collections from outcrops north of lower Sherburne lake in Swift Current valley, and from southern slopes of Chief mountain, were submitted to Mr Stanton, who identifies *Inoceramus labiatus* Schlotheim, *Prionotropis* sp., *Ostrea con-*

gesta Conrad ?, *Camptonectes* sp. *Scaphites ventricosus* Meek and Hayden, *Anomia* sp., *Tellina* sp. Among these the *Inoceramus*, *Prionotropis*, and *Scaphites* are classed as characteristic Benton forms.

The topographic relations of the Dakota outcrop on Kennedy creek and the highest Benton outcrops under Chief mountain are such that if the beds were strictly horizontal the thickness of Cretaceous rocks would be 2,700 feet. As there is a slight dip from the former beneath the latter, this may be increased to 3,500 feet or more. It is, however, possible that the overthrusts which traverse the Algonkian are paralleled by others in the apparently undisturbed Cretaceous beds, and, if so, no estimate of thickness can be based on the meager data now available.

Just northeast of the northern end of Lower Saint Mary lake Weller collected from a gray sandstone and according to Stanton's determination obtained *Inoceramus* sp., possibly young of *I. labiatus*, *Mactra emmonsi* Meek? *Tellina modesta* Meek, *Donax cuneata* Stanton, *Corbula* sp., *Turritella* sp., and *Lunatia* sp. Of these Stanton says:

> "Although the evidence of these fossils is not absolutely conclusive as to the horizon, it is probable that they are from the Benton or at least from some horizon within the Colorado group."

Laramie.—Ten miles east of Lower Saint Mary lake, on the Middle fork of Milk river, occur outcrops of thin-bedded and cross-bedded gray sandstone and arenaceous shale. Some of the layers contain scattered and fragmentary plant remains. Others are barren of fossils. Certain ones are composed of oyster shells. In a section measuring 70 feet Weller found five oyster beds, from which he collected *Ostrea glabra* Meek and Hayden, *Corbicula occidentalis* Meek and Hayden, and small specimens of an undetermined *Melania*, which may be the young of *M. wyomingensis* Meek. The *Ostrea* of the highest stratum is said by Stanton to approach more nearly to *O. subtrigonalis* Evans and Shumard. These are all classed as belonging to the Laramie fauna.

TERTIARY LAKE BEDS OF NORTH FORK

On the North fork of the Flathead there are, as already stated, bluffs of clay with interbedded sandstones and lignites, in which no fossils were found. Details of constitution are summarized in the tabular statement of formations. The materials, degree of induration, and the lignitic condition of the carbonaceous deposits serve to indicate that they may be of Miocene or Pliocene age, as are beds near Missoula, which they resemble. These deposits are called lake beds because they are very distinctly and evenly stratified. They consist of fine sediment, such as would settle from quiet water only, and they occur in a valley of such moderate width between mountains of such height that no simple condition of alluvial accumulation seems appropriate. It is possible that the lake was at times shallow like a flooded river. It is probable that it was some time reduced to the proportions of a river. It is certain that during considerable intervals some areas were marshes; but, admitting that a lake may pass through various phases of depth and extent, the term lake beds best describes these deposits.

PLEISTOCENE (?)—KENNEDY GRAVELS

The typical occurrence of Kennedy gravels is illustrated in figure 2, plate 51. There one may note the size and form of the constituent boulders and pebbles, the incoherent water-washed nature of the gravel shown by the slopes, the level top which falls into the horizon line of the Plains, and the elevated position of the gravel mass. This gravel mesa lies just 5 miles east of the top of Chief mountain, north of and 900 feet above North Fork of Kennedy creek. It is isolated, and equaled in height among the outlying hills only by a ridge of Cretaceous sandstone about 100 feet higher and two miles west of it. The gravel rests on Benton shales, which give rise to many landslides. The Kennedy deposit at this point is something more than 100 feet thick, but its base cannot be accurately placed.

Mr Finlay examined this gravel with care, and the following data are compiled from his notes. The gravel composing the mesa is well rounded or subangular. No striated stones were observed. Boulders two feet across occur, but are rare. Others from 6 to 12 inches in diameter are common. Finer gravel and gravelly soil make up the mass. Of the constituent rocks, limestone and quartzite are most abundant; green argillite forms about 10 per cent; red shale is rarer; Cretaceous sandstone more common. The intrusive diorite of the Siyeh formation is not represented. The gravel deposit is obscurely stratified.

Comparing these notes with Mr Finlay's observations on glacial drift, which covers the slopes 300 to 400 feet below the mesa summit and thence to the creek, it appears that the Kennedy gravels and the drift are alike in being composed of local Algonkian and Cretaceous materials, but differ in that the drift includes many striated stones, and also boulders of diorite from the intrusive sheet in the Siyeh formation. The latter rock does not extend in place into the watershed of North Fork of Kennedy. Boulders of diorite presumably entered the drift in the lower part of that valley by a course on or in the ice when it was confluent with that from Swift Current valley. That the Kennedy formation does not contain diorite boulders is a point in favor of its purely local origin.

The constituent materials, the forms of the boulders and pebbles, the obscure stratification, the topographic form, and the position of the mesa, all characterize this occurrence as a remnant of an alluvial cone of Kennedy creek. No earlier record has been detected in the history of that stream. Since that date, however, the valley has been cut down 900 feet, a glacial epoch has intervened, and the channel has recently been reëxcavated and sunk deeper in the subterrane.

Certain tabular drift surfaces between Swift Current and South Kennedy creeks and on the northern slope of Yellow mountain are probably not of the Kennedy formation, but are outwash plains beyond moraines. Gravel mesas, that are correlative with the Kennedy and may be included under the formation name, occur in Canada, one lying 6 to 8 miles north by west from Chief mountain and east of Belly river; another, a group of three hills, occurring east of lower Waterton lake, a few miles north of the boundary (figure 2). The basis of correlation in these two cases is general form, altitude, and constitution of the masses, which were not, however, examined in detail.

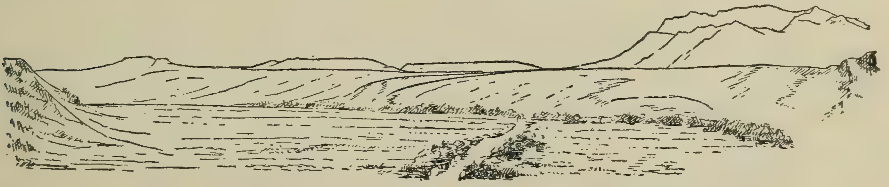

FIGURE 2.—*Sketch of northern End of Lewis Range.*

Showing flat topped foothills of the Kennedy formation standing above terraces of valley drift. Looking east near the outlet of Waterton lake, Alberta, down Pass creek.

Gravels are widely spread on the highest tables of the Plains north of Cutbank river and between the forks of Milk river. Their position suggests a correlation with the Kennedy formation. On the other hand, the gravels of the Plains are composed chiefly of quartzite and presumably have lost the more soluble constituents, which still occur in the Kennedy formation. From this distinction, greater antiquity may be argued for the high level gravels of the Plains. Salisbury, in summarizing the results of Calhoun's observations in 1901 in this region, says:*

> "The high-level quartzite gravels on the plains east of the mountains are believed to be deposits made by streams at the close of the first epoch of baseleveling recorded in the present topography."

If this belief be confirmed, the high-level gravels of the Plains and the Kennedy formation are alike in genesis and derivation from the Lewis range. They may, nevertheless, belong to widely different stages of uplift and erosion. The characteristics of the gravels and the physiographic record of the mountains may decide the relation on closer study.

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* Journal of Geology, University of Chicago, January, 1902.

STRUCTURE

GENERAL STATEMENT

The structural geology of the region comprises three dominant facts, to which all other phenomena are incidental. These facts are, first, the synclinal structure of the Front ranges; second, the superposition of Algonkian strata on Cretaceous in consequence of an overthrust fault, and, third, a normal fault which probably separates the mass of the Livingston range from the equivalent rocks beneath the Flathead valley.

SYNCLINE OF THE FRONT RANGES

General features.—The strata herein described as Algonkian, from the Altyn limestone at the base to the Kintla argillite at the top, are flexed in a shallow basin. Throughout the eastern, the Lewis range, the strata dip gently southwestward. The amount of dip varies from 5 degrees or less to 30 degrees. Throughout the western, the Livingston range, the strata dip northeastward, usually at angles between 30 and 40 degrees. Thus each crest is a limit of the syncline, and the intervening valley follows the synclinal axis with a trend of north 25 degrees west. The structure is of large proportions. The beds involved in the flexure are at least 10,000 feet thick. The width of the syncline is 8 miles near the top of the Siyeh formation, which forms the conspicuous elevated rims, and in the Appekunny argillite, the lowest bed which appears on both sides, it may be measured at 20 miles. The structure is exceedingly simple (figures 1, plates 50 and 51, in panorama, and section 5, plate 53). In broad views irregularities of dip are scarcely noticeable.

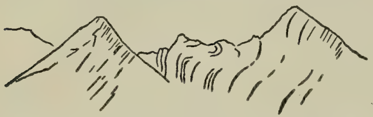

FIGURE 3.—*Mounts Heavens and Stanton, looking south from Trapper Peak.*

Showing the steepest northeastern dip observed.

Details of local folds.—The Grinnell red beds locally exhibit internal folds a few yards in dimensions, representing movements within the soft mass of argillites. In a peak known as mount Stanton, southwest of mount Heavens, on the western margin of the syncline, gray argillites of the Appekunny formation stand vertically, and are even overturned. (See figure 3.) Again, east of the head of lower Logging Creek lake and about 2,000 feet above it, cliffs of this argillite exhibit marked cleavage, which traverses the bedding at an angle of 20 degrees. The local strike of bedding is north 55 degrees west; dip, 20 degrees south-

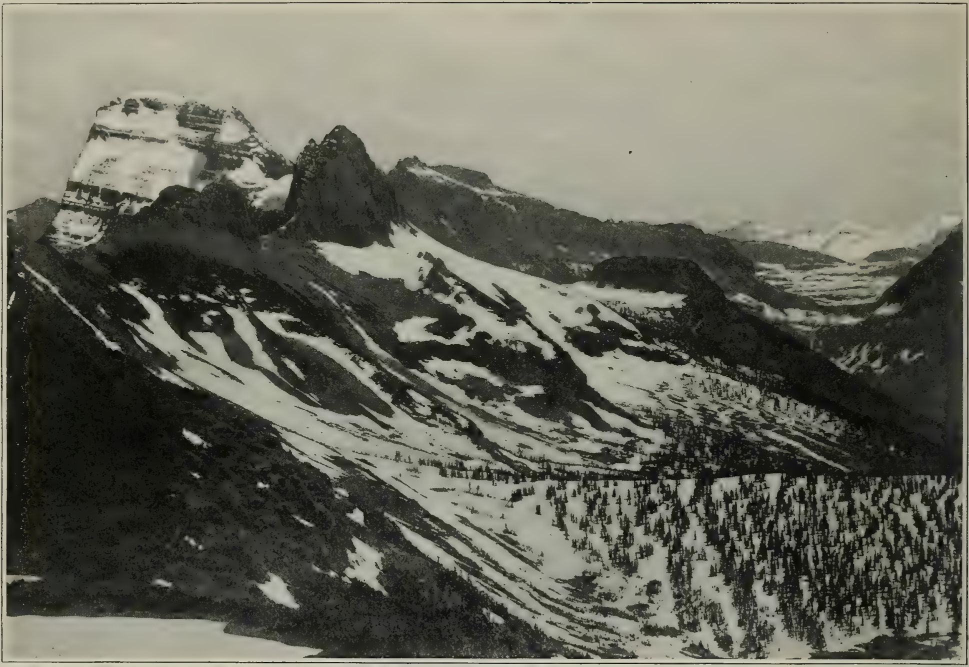

Figure 1.—Panorama from Swift Current Pass, Lewis Range

Looking south by east. East half from Gould on left to Stimpson and Blackfoot far off on right. Foreground of old valley floor continued in plate 51

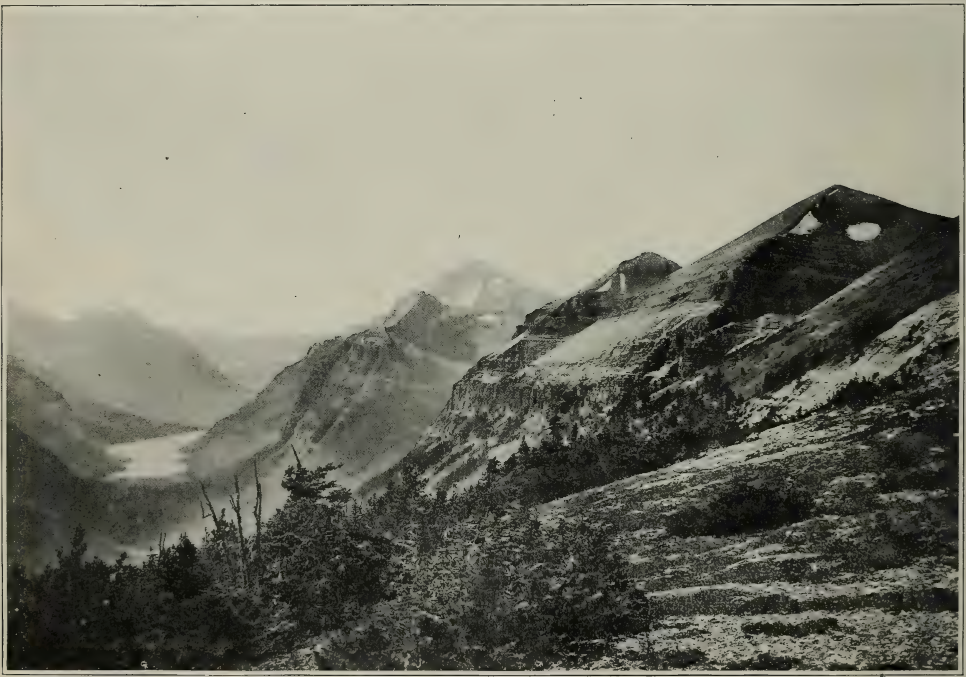

Figure 2.—Upper Knitla Lake and Boundary Mountains, Livingston Range

Looking due west from International summit on Continental divide. Foreground on extrusive diabase underlying Knitla argillite; distant peak, Siyeh limestone; remote hills, Galton range.

PANORAMA FROM SWIFT CURRENT PASS AND VIEW IN LIVINGSTON RANGE

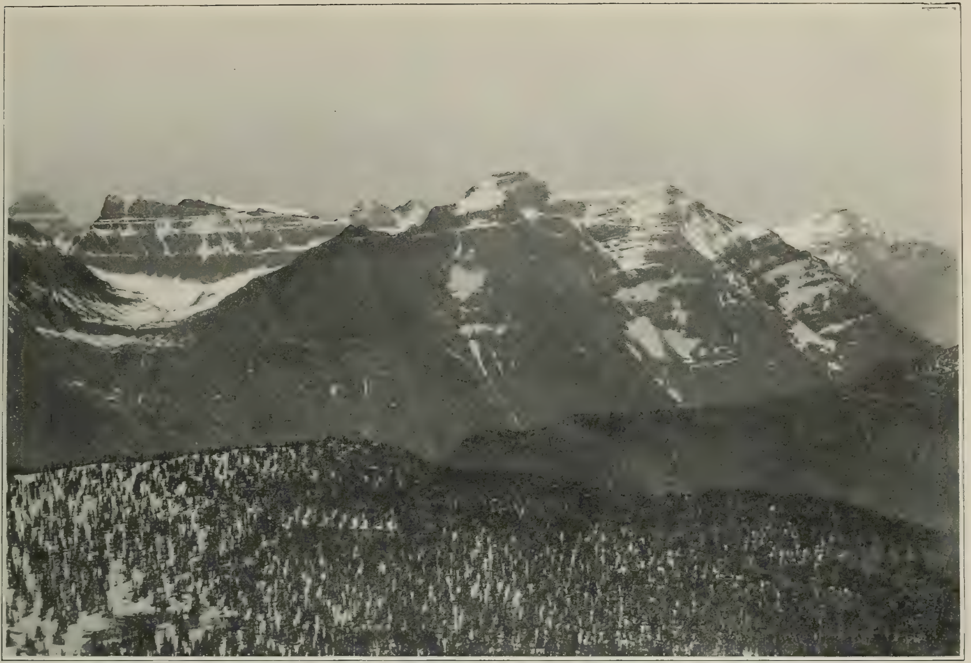

FIGURE 1.—PANORAMA FROM SWIFT CURRENT PASS, LEWIS RANGE

Looking south by east. West half from Reynolds on left to McDonald valley on right. Oblique joint plains are noticeable. Foreground shows canyon of Mineral creek in old valley floor. Continued in plate 50

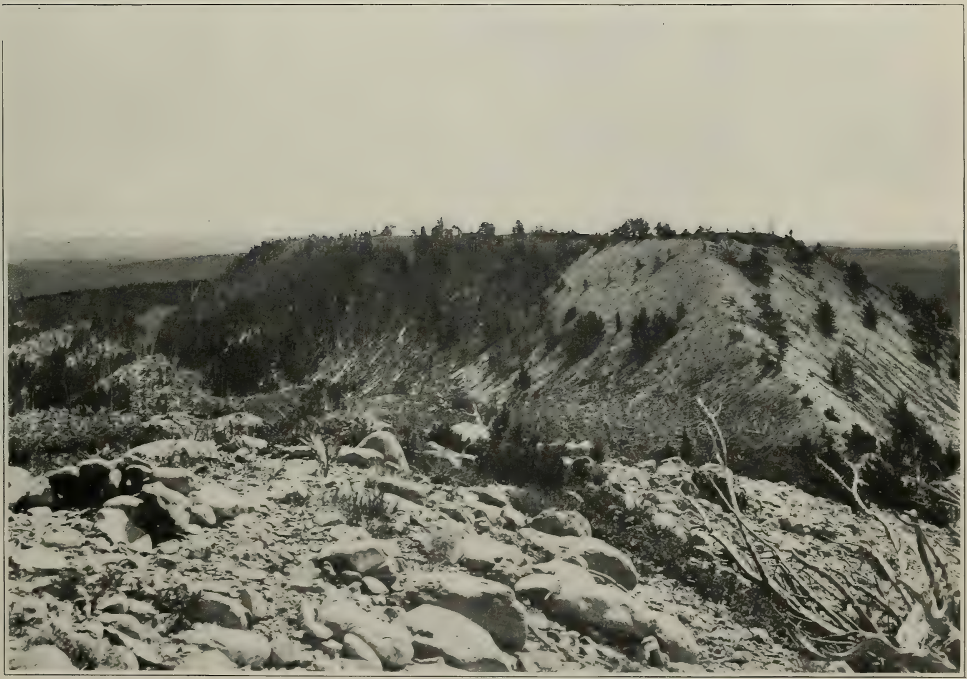

FIGURE 2.—EASTERN FOOTHILLS OF CHIEF MOUNTAIN

Looking east to Great Plains. Typical occurrence of Kennedy high level gravels, 900 feet above Kennedy creek

PANORAMA FROM SWIFT CURRENT PASS AND FOOTHILLS OF CHIEF MOUNTAIN

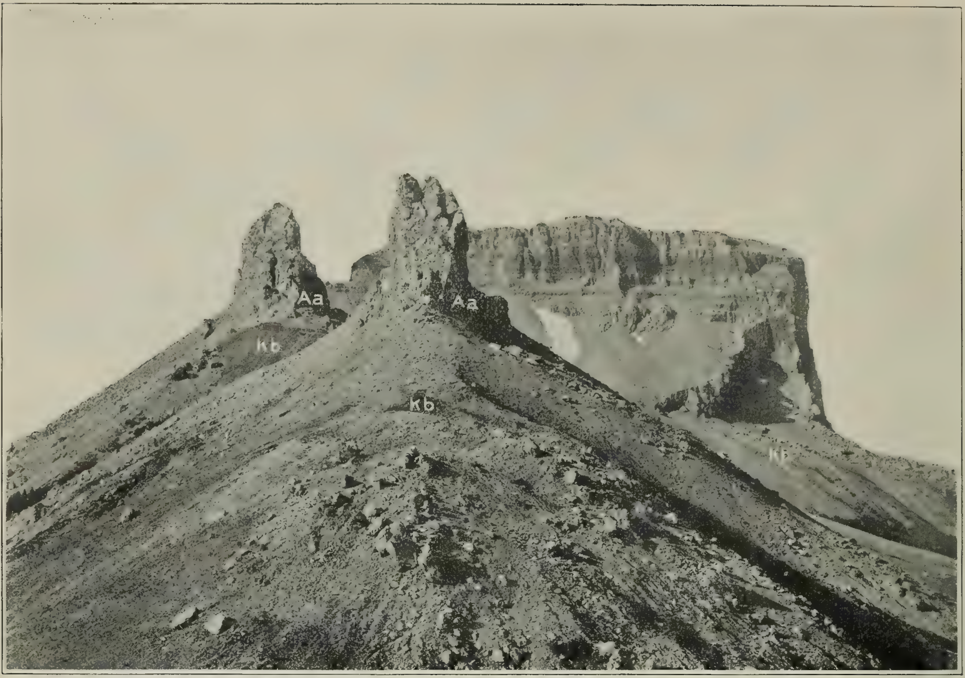

FIGURE 1.—CHIEF MOUNTAIN, LEWIS RANGE

Looking east along Chief Mountain ridge. *Aa* = Algonkian—Altyn limestone; *Kb* = Cretaceous—Benton shale. Upper part Chief Mountain shows upper member Altyn formation

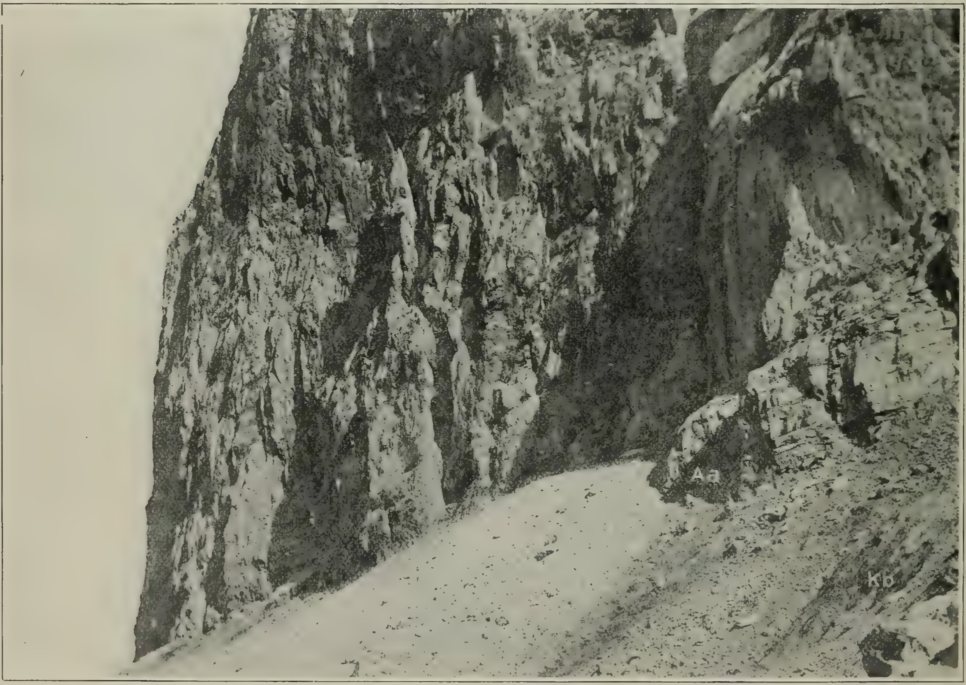

FIGURE 2.—CLIFFS AT NORTHERN BASE OF CHIEF MOUNTAIN

Looking southeast. *Aa* = Algonkian—Altyn limestone; *Kb* = Cretaceous—Benton shale. Limestone exhibits vertical slickenfaces with horizontal motion and in general chaotic fracture

CHIEF MOUNTAIN, LEWIS RANGE

west, and that of cleavage north 45 degrees west; dip, 40 degrees southwest. The structures in mount Stanton and above Logging Creek lake are exceptional. Of a different type is a broad flexure, an anticlinal swell within the syncline. The axis passes through mount Cleveland (elevation, 10,438, the highest in the Lewis range), and thence south 30 degrees east through mount Merritt and mount Wilbur, where the fold dies out. It is noteworthy that the axis carries the major heights of the range. It is a very gentle rise of the strata, usually marked by opposing dips of 5 degrees or less; but in mount Cleveland the northeasterly dip becomes as much as 10 degrees. Between mount Cleveland and Belly river the westerly opposing dip is 20 to 35 degrees.

LIVINGSTON ANTICLINE

The western limit of the Front Ranges syncline is an anticlinal axis, which may be traced just west of the summit of Livingston range in spurs jutting out between Camas and Logging creeks. It is indicated by southwest dips of 5 to 20 degrees, and thus appears to maintain the comparatively gentle inclination of strata observed in the Lewis range in the same direction. Between the high spurs the axis is buried beneath drift which fills the valleys, and northwest from Logging creek no instance of southwesterly dip was observed. Conditions of normal faulting and erosion appear to have resulted in removal of the western limb above drainage lines throughout much of the range.

LEWIS OVERTHRUST

Character and extent.—The simple structure of the Algonkian series overlies a great dislocation. Along the eastern front of the Lewis range Altyn limestone rests upon Cretaceous rocks. This inverted relation was noted from Saint Mary lakes to Waterton lake, a distance of 28 miles in a straight line northwest, and across the general trend the contact was observed to have a width of 5 to 7 miles. The outcrop of Altyn limestone over Cretaceous was observed in a sinuous course, as shown on the map (plate 48 and also figure 4), from Single Shot around the valleys of Swift Current and Kennedy creeks, around the promontories of Appekunny, Yellow, and Chief mountains, past the forks of Belly river and into Canada. The surface of contact was actually seen only beneath Chief mountain, but its position was determined within 20 feet or less at several points. Each series near the contact has yielded fossils, which afford conclusive evidence that in age they are separated by all of Paleozoic and most of Mesozoic time, and that the older is on top. This relation is interpreted as an overthrust (figures 1 and 2, plate 52). A similar structure has been described by McConnell for the same range in latitude 51 degrees.*

Warped thrust surface.—The strike and dip of the thrust plane can not be measured directly, but by graphic construction they may be determined for any triangular area provided the relative heights and horizontal positions of its three corners are known. The topographic map gives these facts within fairly satisfactory limits, and the results are given in figure 4 for five areas between Flattop and Chief mountains. They show that the strike varies from north 15 degrees 30 minutes west to north, and then to north 59 degrees west, and the dip ranges from 3 degrees to 7 degrees 45 minutes.† In these solutions any such area, as that of the triangle Flattop, Swift Current, Appekunny, is considered a plane, which is assumed to coincide with the fault surface. It was observed in the field that the fault surface was curved in cross-sections in the direction of the dip, the dips being exceedingly low, if not truly zero, under East Flattop, Yellow mountain, and Chief, but being also as steep as 10 degrees or more where the overthrust approaches the falls of Swift Current, South Kennedy and North Kennedy creeks. The differences of strike in different segments also show that it is a warped surface. Thus the mathematical determinations of dip and strike are averages, true only of planes which subtend curved surfaces. They nevertheless give valuable indications of the form of the warped surface.

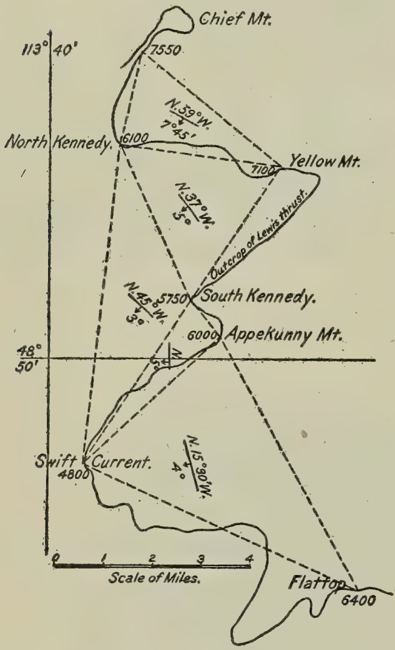

FIGURE 4.—*Diagram of Strikes and Dips of Planes Subtending Areas of the Lewis Thrust.*

So far as the figures go, they show that the strike of the fault surface makes northerly and westerly in a step-like manner, which corresponds to the offset of the mountains about Chief. The prominence and isolation of Chief mountain is in large measure due to the fact that its mass forms the northeastern corner of this offset. West of Chief the strike trends more strongly westward, according to field observations of its position at the forks of Belly, and again more northerly along the western slope of Belly valley. About the northern end of the Lewis range, in Canada (the Wilson range of Dawson), the strike is thought to be to the westward again. From Waterton lake the outcrop of the fault surface follows the base of the mountains northwestward, and the strike approximately coincides with this direction. According to these observations, the relation of the Lewis and Livingston ranges, en echelon at the 49th parallel, is an effect of step-like though very gentle flexure in the fault surface of the Lewis thrust.

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* Canada Geol. and Nat. History Survey, Report 1886, Part II.

† The method of reaching these results is by solution of the simple problem of descriptive geometry: Given the horizontal and vertical projections of three points, to find the horizontal trace and the inclination of their plane.

As to the origin of the flexures in the Lewis thrust surface, several hypotheses suggest themselves. They may be original—that is, the surface may never have been plane. They may have been developed during or after the episode of thrusting movement. They may or may not coincide with flexures of the Algonkian strata; and if coincident as to axes they may not equal the structure of the Algonkian in degree of flexure. Only close studies of the relations with the aid of the complete topographic map will answer the questions thus raised.

Structure beneath the thrust surface.—The structure of Cretaceous strata beneath the Lewis thrust was not connectedly observed. The rocks are commonly covered with drift of talus, and they are much disturbed superficially by landslides, to which the Benton shales give rise. Out of perhaps twenty reliable observations of dip, distributed over the entire area of Cretaceous subterrane, nine-tenths are to the southwest and vary from a degree to 25 degrees. In the field the monoclinal southwestern dip was taken to be a simple structure. From the determinations of Stanton and Knowlton, however, it follows that in this supposed monocline the younger, Laramie, strata underlie the older Benton and Dakota. Such an apparent relation might result (*a*) from the existence of eastward dips along Saint Mary valley, west of Maine, or (*b*) from an overthrust of Dakota and Benton on Laramie, parallel to and beneath the Lewis thrust. Two and a half miles southwest of Maine ridges of Cretaceous sandstone, probably Dakota, exhibit an anticlinal attitude, which may represent an important axis or a local incident. The thickness of the strata and more precise dips must be observed before either of the above possible suggestions can be confirmed or excluded.

Structure above the thrust surface.—The detailed structure of the Algonkian mass above the Lewis overthrust is sometimes chaotic when considered in the small, yet simple when observed in the large. The chaotic structure is best exhibited in Chief mountain, where the lower massive member of the Altyn limestone is crushed (see figure 2, plate 52, and figure 5). The fractures divide the masses irregularly into blocks of all angular shapes varying from a few inches to 25 feet on a side. The surfaces are slickened over wide areas, and where they preserve their orientation in the cliffs the slickens demonstrate much relative horizontal displacement of adjacent fragments. Certain fracture planes are in fact steep fault surfaces along which displacement has occurred in the direction of the strike rather than in that of the dip. Such faults are, however, without apparent system. In other places, as north of Altyn, the cliffs present mural faces traversed by remarkably regular lines of bedding which are crossed by nearly vertical joints (see figure 2, plate 47).

Viewed in the large, the structure of the Altyn limestone sometimes is that of major and minor thrust faults. Yellow mountain, as seen from Chief Mountain ridge, exhibits these relations very clearly (see figure 6). The basal major thrust lies at the foot of the cliffs, somewhat obscured by talus, but sloping about 8 degrees in a curve which on the left is less inclined and descends more rapidly to the right. Springing from it are several minor thrusts, which dip more steeply and which upward pass out either into the air or into an upper major thrust. The upper major thrust is at the base of argillites which dip gently and without appreciable disturbance to the southwest. It simulates an unconformity.

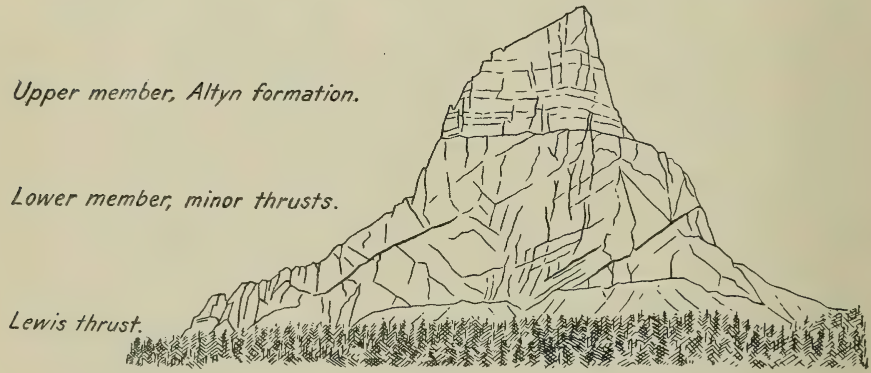

FIGURE 5.—*Chief Mountain, looking north.*

Showing the zone of minor thrusts in massive limestone between the Lewis thrust at the base and the undisturbed upper member of the Altyn formation.

In Chief mountain a similar structure is more strikingly exhibited (see figure 5). The base of massive Altyn limestone is traversed by minor thrusts which are often subparallel to the bedding, so far as it can be made out. These thrusts dip 30 degrees and occupy a zone about 1,000 feet thick above the Lewis major thrust. They are limited above by an upper major thrust which is at the base of nearly horizontal thin-bedded limestones, constituting the upper member of the Altyn formation.

The thickness of strata within which major and minor thrusts are developed is by no means constant. As stated, near Altyn the lowest beds of Altyn limestone present mural regularity of structure, whereas in Yellow mountain probably not more than 500 feet of strata are so repeated as to pile up 2,400 feet high. West of Waterton lake, in the section seen by Dawson, the effects of minor thrusting are still greater; but, though the resulting pile of overthrust segments be great, the maximum thickness of strata involved is probably less than 1,000 feet.

Above the zone of minor thrusting as limited by the upper major thrust the strata are not notably dislocated, if at all, on planes of overthrusting. Nevertheless, it is important to state, as bearing on the distribution of that stress which produced the thrusts, the fact that dividing planes which are parallel to the Lewis overthrust traverse the higher Algonkian strata in the heart of the syncline. The appearance of these planes, which may be called X planes, is given in photographs from near Swift Current pass looking southwest (figures 1, plates 50 and 51). They were also sketched from Trapper peak looking south. In both cases they appeared as elements of the profile or as snow-covered benches on the faces of the cliffs. They cross the stratification, indifferent to the direction of dip. With the field glass no displacement along them could be made out. Nevertheless, whether the strain exceeded the limit of rupture or not, it follows from the parallelism of the X planes and the Lewis overthrust that the stress which produced the system was effective throughout the mass. Between the highest X planes in mount Reynolds, in the

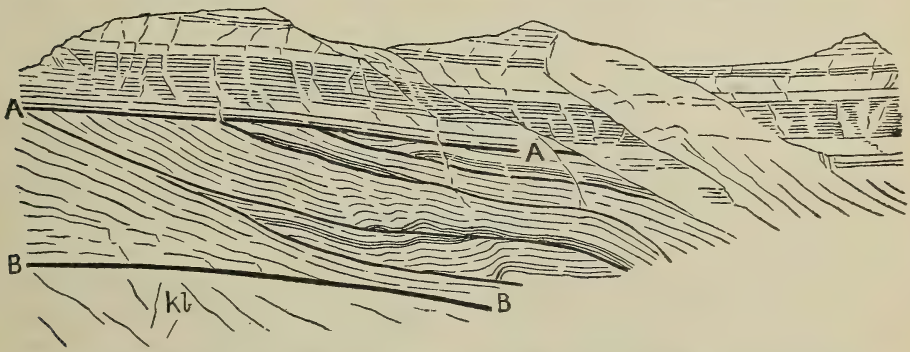

FIGURE 6.—*Structure of Yellow Mountain, drawn from photograph from Chief Mountain, looking southeast.*

AA, upper major thrust under Appekunny argillite. *AB*, minor thrusts traversing and repeating Altyn limestone, minor folding and faulting omitted. *BB*, Lewis thrust. *Kb*, Cretaceous-Benton, much covered by talus.

upper part of the Siyeh limestone, and the Altyn limestone at the Lewis thrust the thickness of strata is something more than 8,000 feet.

STRUCTURAL ANTECEDENTS OF LEWIS THRUST

Explanation.—By structural antecedent the writer means those earlier relations of rock masses from which an existing structure has developed. Thus an overturned anticline is one usual antecedent of an Appalachian thrust fault. The Lewis overthrust is a result of conditions which can now be stated hypothetically only, but which so stated may aid future investigation to a truer understanding. To this end the following hypothesis of its antecedent phases is presented:

Assumptions.—Certain general assumptions may first be stated. The surface of the overthrust is essentially parallel to the bedding of the Algonkian series, and in this particular district to the Altyn formation, where the latter has not been dislocated by minor thrusts. This apparently is true not only of the segments of thrust surface beneath eastern Flattop, Yellow, and Chief mountains, but also of the more deeply buried portion which appears to dip down with the Algonkian strata into the syncline. While observation is not complete, it may be assumed on a basis of fact that thrust surface and bedding are nearly parallel over extensive areas.

As regards structure of the Cretaceous rocks, it is not found that the thrust surface coincides with their bedding or any other internal feature of their mass. But, with reference to physiographic features, it was observed that the thrust plane was apparently continuous with the highest peneplain of the Plains—that is, with the Blackfoot plain, the peneplain which is cut on the upturned edges of the Cretaceous strata. As illustrating this relation, figure 1, plate 47, may be described. On the right is East Flattop mountain, as it appears when one is looking south across Swift Current valley. It is composed of Algonkian strata, in which a white quartzite shows the nearly horizontal attitude. At the base of the cliff, just above the tree-covered slope, is the position of the Lewis overthrust. The wooded slope consists of Benton shales, extensively covered by drift. On the left is Saint Mary ridge, the even crest of which is somewhat built up as a lateral moraine of Saint Mary glacier, but which from this point of view corresponds closely with the profile of the old peneplain. That plain is strongly represented in Milk River ridge, 12 miles east of the brow of Flattop mountain. Its gentle rise westward, about 100 feet to the mile, carries it into the thrust surface beneath Flattop.

This relation of the thrust surface to the peneplain is one of critical importance as a means of determining the antecedents of the Lewis thrust, and it is important to verify or disprove it by more extended observations. So far as detailed topographic data are available south of the 49th parallel, they show that the peneplain must rise materially toward the mountains to cross Saint Mary valley at a height sufficient to meet the thrust surface, and this being so, the eastward slope of the plain and the westward dip of the thrust would occupy anticlinal attitudes, one to the other. It would follow also that the peneplain must be warped, as is the thrust surface, since the elevations possibly common to both are unlike in Flattop, Yellow, and Chief mountains. In general, however, it is true from Divide mountain to Waterton lake that the peneplain may be seen constantly to run into the foot of the cliffs which mark the base of the known Algonkian. Before the overthrust was worked out, the writer observed this peculiar position of the peneplain as one bearing on the physiographic history and presenting difficulties. These difficulties lay in the problem of the relative ages of the topographic features of the plains and those of the mountains. Flattop presents some interesting facts in this connection.

The summit of Flattop is broad, gently sloping, long past maturity in topographic phase. It bears no erratics, striæ, or other signs of glaciation. The rocks of the summit are quartzitic argillites, which are exceedingly resistant to erosion as compared with any rocks on the Plains. The topography of the summit is unsympathetic to its environment and it lies 1,200 to 1,800 feet above the position of the peneplain if the latter be extended to the base of the cliffs. It follows that this past mature topography on hard rocks could not have developed in its present altitude above the plains. Either the surface of the Plains was higher and has been lowered by erosion, or the summit of Flattop was lower and has been elevated by thrust.

If they formerly presented a topographic surface near the level of Flattop's summit hills, the Plains have been degraded 1,200 feet, while Flattop survived as a residual height. The Blackfoot plain on the Cretaceous rocks is so extensive and so completely planed as to indicate a long epoch of erosion, and it seems improbable that Flattop could have retained any part of its ancient summit hills, were they indeed relatively so old.

On the other hand, the summit of Flattop is of that topographic form which would be reached by the harder rocks during the development of the Blackfoot plain on the softer ones. The mass of Flattop rests upon the inclined thrust plane, on which it has been pushed forward at least 7 miles. These relations strongly suggest that the summit of Flattop, once nearly as low as the peneplain, has been pushed upward as well as forward on the incline.

On the evidence presented in the preceding paragraphs it is assumed that the Lewis thrust plane and the Blackfoot peneplain are one, at least as far as the former is now traceable beneath the eastern spurs of the Lewis range.

To these assumptions may be added another based on broad observations of stratigraphy and structure, namely, that a structural effect of the first magnitude in sedimentary rocks was originally conditioned by circumstances of deposition. This thesis was considered at some length in Mechanics of Appalachian Structure* and in an article by Hayes and the writer.†

The three fundamental assumptions thus are: (*a*) The thrust surface coincides essentially with the bedding of the Algonkian series. (*b*) It coincides essentially with the highest peneplain on the Cretaceous rocks. (*c*) The antecedent structures of the Lewis thrust were determined by conditions of deposition.

These assumptions being premised, the development of the several stages may most readily be stated in proper order, from ancient to modern, and in simple assertive style. It may be understood that the writer is conscious of the unproved character of some of the points.

Antecedents by deposition.—The first stage considered is that of Cretaceous deposition (see section 1, plate 53). The Dakota epoch of the Cretaceous period was one of wide invasion of the sea westward and northwestward. The deposits in this region contain freshwater shells, and may be considered as having formed in estuaries or lagoons. They are succeeded by marine deposits (Benton), which may be followed by other formations of the Cretaceous system, but of these only the Laramie is identified. Dawson ‡ gives a section of 8,290 feet of Cretaceous in the foothills of the Rocky mountains. We have reason to think there are more than 3,500 feet of Dakota and Benton under Chief mountain. The surface beneath the Dakota formation was a plane; primarily a peneplain; subsequently a surface of marine planation. It sloped gently eastward, and was practically flat in its early history. As it subsided and was buried under marine deposits, it was no longer flat, but curved in gentle flexures, according to any inequalities of subsidence (see section 2, plate 53). Variations in thickness of strata are among the evidences of unequal subsidence, and had we good measures of the Cretaceous strata, we might demonstrate a point of first importance in the hypothesis. As it is, we must rely on the special case of a shore. As Cretaceons rocks do not occur west of the Lewis range in the region

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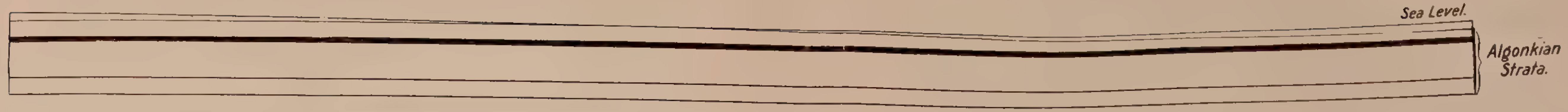
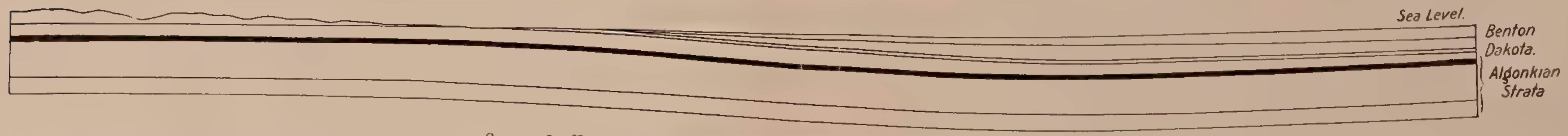
* Thirteenth Annual Report U. S. Geol. Survey, p. 253 et seq.

† American Journal of Science, Third Series, vol. xlvi, pp. 257-268, Conditions of Appalachian Faulting.

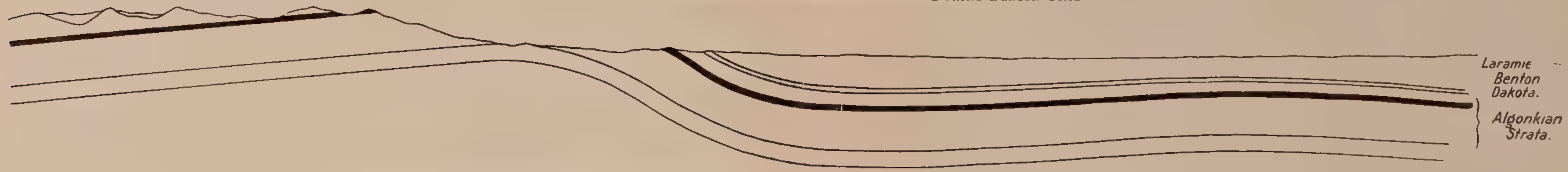
‡ Canada Geol. Survey, Report 1885, p. 166 B.


Sea Level.
Algonkian Strata.

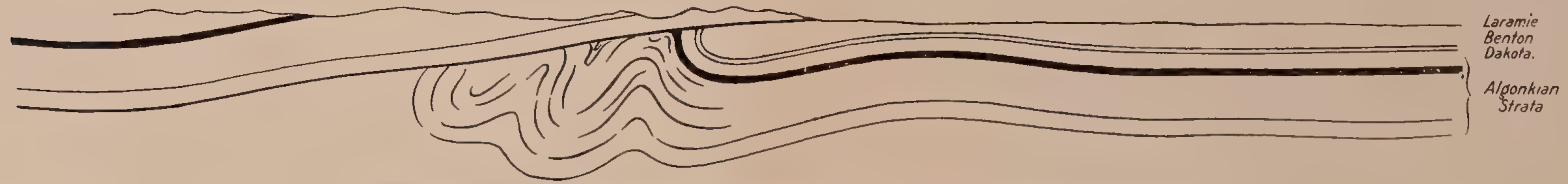
SECTION 1.—HYPOTHETICAL STRUCTURE AND SUBAERIAL AND SUBMARINE PROFILE OF NORTHWEST MONTANA IN DAKOTA TIME


Sea Level.
Benton
Dakota.
Algonkian Strata

SECTION 2.—HYPOTHETICAL STRUCTURE AND DEPOSITS DEVELOPED DURING BENTON TIME

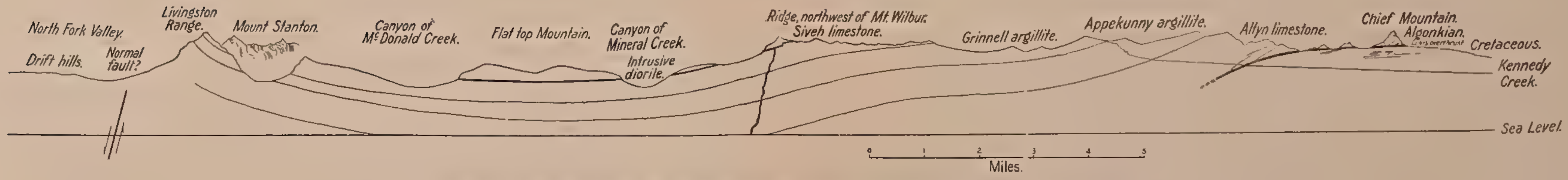

Laramie
Benton
Dakota.
Algonkian Strata.

SECTION 3.—HYPOTHETICAL STRUCTURE AND SUBAERIAL PROFILE RESULTING FROM EARLIER EPISODE OF POST-LARAMIE DEFORMATION


Laramie
Benton
Dakota.
Algonkian Strata

SECTION 4.—HYPOTHETICAL STRUCTURE RESULTING FROM LATER (POST-BLACKFOOT CYCLE) EPISODE OF DEFORMATION

Scale of Miles,
for hypothetical sections.
0
5
10
15


North Fork Valley.
Drift hills.
Normal fault?
Livingston Range.
Mount Stanton.
Canyon of McDonald Creek.
Flat top Mountain.
Canyon of Mineral Creek.
Intrusive diorite.
Ridge, northwest of Mt. Wilbur.
Siyeh limestone.
Grinnell argillite.
Appekunny argillite.
Allyn limestone.
Chief Mountain.
Algonkian.
Cretaceous.
Kennedy Creek.
Sea Level.
0
1
2
3
4
5
Miles.

SECTION 5.—OBSERVED SECTION OF THE FRONT RANGES FROM CHIEF MOUNTAIN TO NORTH FORK VALLEY

Topographic profile based on contour map, Chief Mountain quadrangle, U. S. Geological Survey

GEOLOGICAL SECTIONS

under discussion, it is probable that the Dakota-Benton sea did not extend many miles west of the present limit of the Plains in this latitude. A shore established on a flat surface and remaining nearly fixed during an episode of deposition in an adjacent zone is a line between an area of subsidence and one of uplift. The case is one of markedly unequal subsidence, the movement being on the one side plus, on the other minus. The sequence of changes is shown in sections 1 and 2, plate 53. Section 1 represents the condition during the Dakota invasion. Section 2 shows the effects of subsidence and uplift incident to deposition of 4,000 feet of Dakota and Benton sediments. The drawings are to natural scale.

The surface on which Dakota sediments gathered probably consisted of Carboniferous and Algonkian rocks. The observed angular unconformity beneath the Carboniferous is slight. The present deformation of the Algonkian is apparently attributable altogether to post-Cretaceous movements. It is assumed that the Algonkian strata were essentially flat in Dakota time and were bent in consequence of the subsidence which occurred during Benton time. These assumptions also are shown in sections 1 and 2, plate 53.

Whatever later stages of deposition followed may have been accompanied by further subsidence and curvature, but that which is attributed to the Benton epoch is sufficient to occasion the development of an anticline (section 3, plate 53) whenever compression should occur.

The preceding statement is made to show reason why an anticline should have developed near the present site of the Front range. Its essential principle is that of initial dips, as a condition which determines the loci of anticlines and synclines,* and the special case is based on the probable position of the Dakota-Benton shore. In what follows the episodes of deformation and erosion leading to the present relations are discussed.

Antecedents by folding and erosion.—Along the eastern base of the Rocky mountains in general the facts of structure express the action of a compressive stress, the Cretaceous and older strata being folded. The post-Cretaceous effects are commonly attributed to a single episode of compression; in what follows they are assigned to two episodes, at least for the particular district under discussion.

The first episode of compression began at some date not closely determinable, but which may be placed not earlier than Laramie time, nor later than early Tertiary. It is possible that flexure went on during Laramie deposition. It is also possible that it did not begin till after that deposition was completed. The distinction is not important to the present thesis. Flexure in its early stages was an effect involving relatively great stress, as the nearly flat Algonkian strata were exceedingly inflexible. It is probable that folds developed slowly. As the Laramie sea was shallow and was succeeded by emergence of the area, the anticlines were subject to erosion, whether they developed earlier or later, and the synclines received their waste either as sediments beneath marine waters or in estuaries or in lakes or as valley deposits.

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*Mechanics of Appalachian structure, op. cit., plates showing models A to E 1.

The effect which for a time satisfied the compressive stress was one of moderate folding (see section 3, plate 53). The succeeding condition was one of quiescence and it endured long enough for the planation of Cretaceous rocks to the Blackfoot peneplain. The name Blackfoot may be extended to the topographic cycle ending in the development of the plain. The Blackfoot cycle can not be accurately dated by any evidence now available. It was post-Laramie and probably earlier than the orogenic movements which, in Montana, gave rise to ranges and lake basins. The latter having yielded Miocene vertebrates, the movement may be placed in mid-Tertiary. That it was preceded by the Blackfoot cycle is an inference based on general observations of an extensive peneplain over the summits of the Rockies of western Montana and Idaho, observations which leave no doubt in the writer's mind of the existence of such a peneplain, but which do not suffice positively to identify it as the Blackfoot plain. On the probability of that identification the Blackfoot cycle may be placed in early Tertiary time.

At the close of the Blackfoot cycle the topographic features of the region under discussion were the peneplain on Cretaceous rocks and low hilly, past-mature relief on Algonkian rocks, such as is now presented by the summit hills of eastern Flattop. To illustrate them would require a profile differing from that of section 3, plate 53, only in degree of relief.

Conditions of overthrusting.—Among the effects of folding and erosion, at the close of the Blackfoot cycle was the exposure of the edges of some Algonkian strata as outcrops; being gently inclined westward, these beds had probably wide extent underground. They were relatively stiff and lay with one edge free. Under these conditions, supposing that a compressive stress again became effective, a part at least of the Algonkian beds were so placed that they met but slight resistance in their tendency to yield by moving forward. So far as they were unopposed, or not sufficiently opposed to check and fold them, they did ride forward (see section 4, plate 53). That part which was thus overthrust separated from that which was not in general along bedding planes near the base of a particularly rigid stratum, such as the Altyn limestone.

The Siyeh limestone, the Carboniferous limestone, or other stiff formation may elsewhere be found to have determined the thrust surface within the old rocks.

Associated structures of the Lewis thrust.—At the margin and beneath the advancing overthrust mass, the effect should be to disturb a superficial layer of greater or less depth. Strata might be overturned; or, if rigid, they might be pushed forward on a thrust plane parallel to the initial thrust; or in soft shales like the Benton, confused crushing might ensue. The weight of the overriding Algonkian might be that of a few hundred or of several thousand feet of rock. In Flattop the thickness is 1,800 feet or less; in Chief it is 1,600 feet. Along the advancing margin it would not in any case be that of the series of Algonkian strata observed in the syncline of the Front ranges. The weight would not be sufficient to restrain rocks from breaking, and the local effects of deformation would be fracture, accompanied by irregular but extensive displacement. These deductions in part correspond with the observed conditions of the overthrust and underthrust masses.

The surface on which the overthrust mass would ride forward would practically coincide with the Blackfoot plain, with which the thrust surface would thus become identified, but it is probable that in the process the peneplain would be deformed. In underlying strata not taking part in the displacement, the stress from which the overthrust resulted should have been exerted to accentuate any previously existing flexures. The Lewis anticline, if the structural antecedent of the Lewis thrust may be so called, was probably paralleled by a gentler fold somewhat further east, as a result of the earlier stage of compression. Any rise of that fold during the later stage of compression would be expressed in arching of the Blackfoot plain; such arching as exists, in fact, if the peneplain and the thrust surface coincide along the eastern base of Lewis range. An experimental illustration of an overthrust, a parallel fold, and the coincidence of thrust surface and subaerial plane may be seen in the sections of model E1, Mechanics of Appalachian Structure.

The displacement observed on the Lewis thrust is 7 miles; the actual displacement is probably greater. The superficial movement requires accommodation of subterranean masses to an equivalent amount in some manner. This adjustment does not affect the preceding discussion of the development of the thrust, but it is a phase of the subject which is naturally suggested in sequel. In section 4, plate 53, close folding of strata is indicated in a position corresponding to a place beneath the Lewis range, but both the manner of folding and the locus assigned it is suggestive only. Applying the general rule that the nature of deformation is determined by the character of rocks and the superincumbent load, the adjustment may consist in fracture, in flow and fracture, or in flow, and at successive depths deformation related to the Lewis thrust no doubt takes on the corresponding forms of crushing, folding, and viscous flow. The meridional sector in which such shortening may take place is indeterminate. It may correspond with the meridian of the Lewis range or extend eastward or westward. General relations suggest that a western sector moved relatively toward an eastern, which was stationary; but the mechanical effects would be similar if an eastern had moved against and under a western mass, or if they had both been in motion each toward the other. The facts thus afford no certain basis of conclusion as to the locus of deeper-seated shortening, corresponding to the Lewis thrust.

The relation of the Lewis thrust to the syncline of the Front ranges presents interesting questions. Did they develop successively or simultaneously? If successively, the broad mechanical effects may have been produced in either order, namely, the thrust first and the syncline later, or *vice versa*. If simultaneously—that is, as effects of a single episode of compressive stress—the manner in which the force was distributed, partly in thrusting and partly in folding, may be definitely analyzed. Let it be assumed that as a result of the earlier compression the Algonkian strata were bent in a synclinal flexure of less pronounced character than the present one. Then, in the later compression, the stress transmitted through the series was resolved into two components—the one tangential, the other radial to the bedding. The former was adequate to cause thrusting; the other was competent to increase the curvature of the beds. For a given stress the ratio of these two components changed with the increase of curvature, the tangential component losing as the radial gained. Thus thrust would cease when the tangential became inadequate to overcome the resistance opposed to it, and curvature would increase till the stress was taken up in the growing anticline west of the syncline. One effect would be to concentrate folding along the western margin of the syncline and to produce steeper dips toward the northeast than those toward the southwest. Such is the fact, but it might have arisen in other ways also. Another result would be to give to the thrust surface a synclinal form, but one which would be less pronounced than that of the overlying strata; and, again, the topographic surface developed on Algonkian rocks during the Blackfoot cycle should be depressed along the synclinal axis to an amount corresponding to the degree of flexure suffered by the strata during the later compression. This point is again referred to under physiographic problems.

Date of the Lewis thrust.—On the hypothesis of a single episode of compression, from which resulted all the phenomena of folding and thrusting in Cretaceous and Algonkian rocks in the district, the Lewis thrust and the associated structures must be assigned to a date closely following the Laramie deposition. The growth of the Front ranges and the development of the Blackfoot plain must be placed later, and the expression of the Lewis thrust must be considered subordinate at the surface to these later effects of orogeny and erosion.

On the other hand, on the hypothesis of two episodes of compression, separated by the Blackfoot cycle, the Lewis thrust must result from the second episode, and falls probably in mid-Tertiary. Its orogenic effects are then dominant in the Front ranges, and the physiographic history is to be read in terms of structure as well as of erosion.

It is concluded that the data of the Lewis thrust may be placed in either late Cretaceous or mid-Tertiary time, and the principal criteria for determining which date is correct are to be found in the relations of structure to physiography.

NORTH FORK NORMAL FAULT

Topographic relations.—The valley of North fork of Flathead river is apparently a structural valley of much greater length than the watershed which coincides with its southern portion. The form of the valley is long as compared with its width. The North fork has no extended tributaries, but streams from the western side have more extensive basins than those from the eastern, which are notably short. There is marked contrast in the aspect of the mountains, west and east. Those on the west, the Galton range, are broad and massive (distance of figure 2, plate 50); they attain heights of 7,000 to 7,500 feet above sea, and they are traversed by open, V-shaped valleys. Those on the east, the Livingston range, are abruptly precipitous, vary in altitude from 8,000 to 10,000 feet, and present acute peaks rising from U-shaped valleys. Over the summits of the Galton range the lowland topography of an earlier cycle is easily traced; in the Livingston range that cycle has not been recognized. A long slope extends from the heights of Galton to the valley; abrupt rise from hills of drift characterizes the western spurs of Livingston.

Geologic relations.—The geologic relations in a cross-section of North Fork valley are simple. Proceeding from southwest to northeast in the vicinity of Hay and Bowman creeks, one encounters: In Galton range, calcareous argillite, probably of the Siyeh formation, lying with a dip of

30 degrees northeast; in Flathead valley, drift and lake beds; in Livingston range, Appekunny argillite, dipping 30 to 45 degrees northeast. The dip of the Siyeh formation in Galton range carries it under Flathead valley to a position several thousand feet below the Appekunny beds, which it properly overlies. The relations are those of a normal fault of great displacement, and downthrow on the west.

From the topographic relations the position of this normal fault is inferred to be along the base of Livingston range, the downthrown block underlying Flathead valley.

Date of normal faulting.—By reasonable inference the lake beds of North fork are connected with the normal faulting. The strata are tilted to a dip of 14 degrees northeastward toward the fault, as though they had shared in late movements. The date of faulting is thus tentatively fixed as Miocene or possibly Pliocene. Elsewhere in Montana similar faults are related to lake basins which have yielded Miocene vertebrates and, pending exact determinations, the North Fork fault is assigned to Miocene rather than Pliocene.

This conclusion has been anticipated in placing the latest probable date of Lewis thrust as mid-Tertiary; for the normal fault has resulted in a detachment of Livingston range, such that the strata could not in their present position receive the pressure which overthrust and flexed them. It follows that the thrusting must have preceded the normal faulting—that is, must have been accomplished by Miocene time.

STRUCTURE AND PHYSIOGRAPHY

Great plains and Front ranges.—Recognition of the tilted attitude of Cretaceous strata and of the even surface extended across their edges is sufficient to demonstrate the character of the Great plains, at least in the belt adjacent to the Front ranges. The surface is one of planation, independent of structure, and, marine planation being excluded on strong negative grounds, it may be considered a peneplain. Several stages of erosion may be noted in the relief of the Great plains, but the one here referred to is that which is represented by the highest levels and which is oldest. In the preceding discussion of antecedents of the Lewis thrust it was named Blackfoot peneplain and assigned to a pre-Miocene cycle of erosion. It is well represented in Milk River ridge between Cutbank creek and South fork of Milk river, west of the 113th meridian, where its elevation above sea is between 5,000 and 5,100 feet.*

The rise of the Lewis range above the Blackfoot plain is more than is reasonably attributed to difference of hardness of rocks. Limestones and quartzites could not have maintained such relative altitude so near a lowland in which shale and sandstone were reduced to a plain. The later forms sculptured in the Blackfoot plain are apparently represented by equivalent features in the Front ranges. When their correlation has been worked out, remnants of a surface may be recognized as belonging to the Blackfoot cycle in old age. They may be traced among high shoulders of the peaks, which must then be considered monadnocks, or they may be the tops of peaks. In the latter case the surface may appear closely to conform to the highest summits of the crests and to lie above the structural valleys. The criteria which effect this alternative can better be discussed when the structural factors shall have been estimated.

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* See the Browning atlas sheet of the topographic map of the United States.

The relatively great altitude of the Lewis range, considered as a result of mountain growth, might be attributed to a monoclinal flexure or a normal fault; but there is neither monoclinal flexure nor normal fault between the Lewis range and the Plains. There is, however, a great overthrust, and it is appropriate to consider the quantitative sufficiency of the thrust to produce the difference of elevation. Eastern Flattop mountain furnishes most satisfactorily the data for estimate. Its surface is topographically old. It may represent the Blackfoot peneplain as far as it developed on silicious argillite, or it may have suffered some erosion in initial uplift immediately preceding the thrust movement. In the latter case the surface which should be compared in altitude with the Blackfoot plain lies somewhat above existing features. The highest hill on Flattop, a low, rounded summit of bare rock, is 8,340 feet above sea. It is reasonable to place the ancient surface not above 8,500 feet, or not more than 3,500 feet above the Blackfoot plain, in Milk River ridge. By reference to figure 4 it will be seen that the dip of the thrust plane beneath Flattop is about 4 degrees, with a corresponding displacement of 4 miles. The vertical component, or vertical throw, of the thrust for this section is a little less than 1,500 feet. The observed displacement of Flattop is 7 miles, leaving 3 miles not reckoned in the above figures, and the dip is known to become materially steeper as the thrust descends. If the average dip for 3 miles below the outcrop at Swift Current falls be 7 degrees (or about that determined southwest of Chief), the vertical component of the thrust would be a little more than 1,900 feet. The two estimates should be added, and their sum is 3,400 feet. In these figures the only one not checked by observation is the dip of 7 degrees below the outcrop, but it is less than would be estimated on the basis of observations near Swift Current falls and on North fork of Kennedy.

The writer concludes that the altitude of the Lewis range above the Great plains is due to the vertical throw of the Lewis overthrust; and also conversely that the observed displacement on the Lewis thrust nearly approaches the actual, since much greater displacement on the probable dips would have resulted in greater elevation.

Heights and anticlines.—In northern Lewis range and in Livingston range greatest altitudes are in general related to anticlines. In Lewis range an anticlinal axis already described is definite in mount Cleveland (10,438 feet above sea), swings southeastward about the head of Belly river near mount Merritt (9,944 feet), trends again southward through mounts Wilbur (9,293) and Gould (9,541 feet), and is lost in an expanse of nearly level strata centering about Citadel (9,024 feet). In mount Cleveland, where the anticlinal is narrow and dips from the axis exceed 10 degrees, the altitude is the greatest of the range. In mount Merritt the fold is broader and dips are 5 degrees or less. Farther south the arch is merely a leveling of the southwesterly dip, with reference to which it occupies a lower monoclinal position, and the heights named above are also lower than others which lie farther east. Thus Siyeh (10,004), Going-to-the-sun (9,594), and Little Chief (9,542 feet) lie east of the anticlinal zone and are cut from elevated edges of hard strata dipping southwest. The many heights slightly above or below 9,000 feet, which are grouped between McDonald lake and the headwaters of Saint Mary river, appear to correspond with the widening area of level strata. The anticlinal axis winds from north-south to southeast and back to south, and Lewis range trends with it. Where the axis widens to a bench in the southwest-dipping monocline the range also widens and loses its distinctive crest. Thus there is a relation between altitude as expressed in peaks and elevation due to folding, and there is also a general relation of mountain belt to anticlinal zone.

In Livingston range an anticlinal axis may be noted west of mount Heavens (8994) and near the head of Logging lake, where a group of nameless peaks reaches 8,500 feet. The arch crosses spurs jutting southwestward from the crest, which is on the eastern anticlinal limb. Beyond Logging lake northwestward the mountains rise to heights between 9,000 and 10,000 feet, but the axis was not observed. It probably is cut off and thrown down by the North Fork normal fault. The position of the crest is an accident of erosion due to the work of streams and glaciers, which under favoring conditions of slope and exposure have forced the divide eastward till it is now from 1 to 4 miles east of the anticline. In general, however, the summit follows the trend of the fold, and the two may reasonably be considered as being related.

Valleys and synclines.—In the Front ranges valleys fall readily into two classes, namely, (1) valleys independent of structure and (2) valleys related to structure. Saint Mary, Swift Current, and Kennedy valleys belong to the first class; they are effects of streams of water and ice cutting retrogressively headward across the edges of strata which dip away from their direction of fall. Waterton and upper McDonald valleys belong to the second class, and to them alone need consideration be given here.

To an observer on central Flattop mountain the synclinal structure of the Front ranges is the obvious fact (figure 1, plate 50, and figure 1, plate 51, in panorama). Scarcely less apparent is the broad synclinal valley of which the summit of Flattop was formerly the floor. For a distance of 12 miles from northwest to southeast the relation is exceedingly direct. The summit of Flattop has a general elevation of 6,800 feet and the axis of the syncline is parallel to its trend, and northeastward and southwestward the mountain slopes and the strata rise to the crests of Lewis and Livingston ranges respectively. The syncline pitches northwestward, but is drained southeastward by McDonald and Mineral creeks, which, united, flow out southwest. This condition may be attributed to capture and inversion of a stream which was formerly consequent on the pitch. Southeast from and in line with this synclinal valley, shutting it off at that end, is the group of mountains of which Reynolds is a representative. Their relatively great height, 2,000 feet above Flattop, may be due to rise of resistant limestone and quartzite on the axial pitch. In the other direction Little Kootna creek and Waterton river lie over on the eastern limb of the syncline and crossing the dip on a long slant escape to the plains, while the synclinal axis coincides with peaks that rise to 9,000 feet. The divide, however, is farther west. The unsymmetrical position of Waterton river may be due to conditions preceding folding or to capture following on it; but its drainage basin is within the syncline, limited by the anticlines of Lewis and Livingston ranges.

Thus, as might be expected, there are details of stream arrangement which have resulted from adjustment. They have also been affected by glaciation, but the broad fact of a synclinal valley between anticlinal heights is dominant.

Distinctive character of Front ranges.—The Front ranges are distinguished from physiographic districts adjacent to them by the dominant influence of structure on altitude described in the preceding paragraphs.

In strong contrast, the Great Plains exhibit features of erosion entirely independent of structure. Galton range, though as a mass bounded by structural limits, is within itself apparently a simple uplifted block. Whatever minor flexures or faults may exist, near the 49th parallel they are not sufficiently pronounced to interrupt the unity of the mountain mass. While the general altitude of 7,500 feet is due to uplift, details of heights express effects of earlier or later erosion only. In this respect Galton range is like the Plains and unlike the Front ranges.

Over the Plains and over Galton range a peneplain was developed. On the soft rock of the Plains it was planed flat. On the harder rocks of the Galton mass it was probably not so completely smoothed. Observations of 1901 were neither so extensive nor so precise as to distinguish monadnocks from features of later carving, but the general relation of height to an old lowland is as distinct as it is on the Schooley plain, in the Highlands of the Hudson, New York. The peneplain on the Great plains, the Blackfoot plain, is neither incidental nor local. It is the result of a long cycle of erosion, which affected a wide territory, and its representative must occur in the nearby mountains among the oldest features, if not as the oldest, unless it has been obliterated by later activities. A tentative correlation of the Blackfoot plain with the peneplain over Galton range is a reasonable inference from these facts. Nevertheless, in the intervening Front ranges the observer seeks in vain for that general uniformity of altitudes or that breadth of contour which might represent the Blackfoot plain.

Recognition of peneplain in the Front ranges.—The peculiarly bold sculpture of the Front ranges is explicable, offhand, as an effect of great elevation, from which there resulted special conditions of glaciation and erosion. It resembles the sculpture of the Cascade range, Washington, as nearly as is consistent with diversity of rock types. But unlike the Cascades, whose summits inherit common altitudes from a broad peneplain, the Front ranges exhibit no general upper limit of heights common to many widely distributed peaks. Instead, they present an extreme case of localized deformation, accentuated by intense corrasion. Realizing this, one may still recognize the position of the oldest topographic surface of the province near the summits of the ranges. It is notable that each peak approaches in height those of its neighbors which stand in similar structural positions—that is, along the strike. A surface restored over the peaks, or over their wider shoulders, should represent that from which they are carved, plus or minus the effects of warping and minus the effects of later erosion. Detailed observations of structure will determine the former; studies of stratigraphy in relation to sculpture will evaluate the amount by which erosion has reduced altitudes relatively on the several rock types—argillite, limestone, quartzite, and diorite. The determinations may be checked on some surviving areas of ancient relief. When existing profiles have been raised or lowered in accordance with these values, there will result a surface, which, in the writer's judgment, will closely correspond with the peneplain over Galton range. The conclusion involves elements which the eye cannot rightly estimate in the field and for which precise data are not at hand. For this reason the writer is disinclined definitely to place the peneplain relatively to the heights of the Front ranges; but, recognizing the insignificant extent of summit areas, or of shoulders that might support modified monadnocks, he thinks it may be located on top of the highest peaks rather than below them.

On the same ground of inadequate data, the extremely intricate problems of sculpture must be left to the future. The student who may read the record will find it replete with facts of waterwork and icework, and he may discuss evidences of distinct episodes of uplift or of glaciation which the writer has not ventured to interpret.

Igneous Rocks of the Algonkian Series

By George I. Finlay

GENERAL COMMENT

Occurrences of igneous rocks in the Front ranges, so far as observed, are limited to the Siyeh formation and a dike in older rocks on Trail creek west of Waterton lake. The drift of the North Fork valley contains boulders which represent other rock types.

The igneous rocks of the Siyeh limestone are two—an intrusive diorite and an extrusive diabase. They are described below. The dike on Trail creek is a diabase.

DIORITE

On mount Gould and on mounts Grinnell, Wilbur, and Robertson there is found a band of diorite 60 to 100 feet thick. Near the upper and lower surfaces this intrusive sheet was chilled and is fine-grained. In the center the texture is medium or fine-grained. Several dikes which have acted as conduits for the molten rock are exposed in the region near Swift Current pass. One of these extends across the cirque occupied by the Siyeh glacier and runs vertically up the amphitheatral walls. It is 150 feet in width. A second dike, vertical and 30 feet wide, comes in beside the Sheppard glacier. Along the trail to the east of Swift Current pass the diorite sheet breaks across the Siyeh argillite and runs upward as a dike for 500 feet. It then resumes its horizontal position as an intercalated sheet between the beds of argillite. As a dike it skips for 600 feet across the strata on mount Cleveland.

Under the microscope the diorite is found to contain abundant plagioclase, with small amounts of another feldspar, much weathered, which does not show twinning. This mineral is closely intergrown with quartz. Brown hornblende is the principal dark silicate. The plagioclase has an extinction angle high enough for labradorite, but it gives no definite clue as to its exact basicity. No section of a fresh piece twinned on the albite and Carlsbad laws at the same time could be observed. The quartz is not present in sufficient amounts to make advisable the name quartz-diorite for the rock. The small patches of biotite originally present are entirely altered to chlorite. Pyrrhotite is occasionally met with, apatite occurs in crystals of unusual length, and magnetite in lath-shaped pieces is common.

DIABASE

In the field this rock is always much weathered, presenting a dull green color by reason of the secondary chlorite which it contains. It is a typical altered diabase. Exposures are found near the top of mount Grinnell, where the thickness of the sheet is 42 feet, and on Sheppard mountain opposite mount Flattop. Here the extrusive character of the flow is well shown, for its upper surface is ropy and vesicular, with amygdaloidal cavities containing calcite. Its place is at the top of the Siyeh formation, 600 feet above the sheet of diorite, with heavy bedded ferruginous sandstone and green argillite immediately below and above it respectively. The argillite has filled in the irregularities of the upper surface of the diabase. Five dikes of the same rock, genetically connected with it, were observed on Flattop. They contain inclusions of the argillite, and range from an inch to 6 feet in width. They are nearly vertical.

Under the microscope the rock is seen to be made up principally of augite and plagioclase, arranged in such a manner as to give the normal diabase structure. The plagioclase is idiomorphic in long, slender laths. It has the habit of labradorite, but no material was studied which offered data for its accurate determination. The extinction angle is high. The augite is much more abundant than the feldspar. It is an allotriomorphic mineral, red-brown when fresh, but frequently entirely gone over to chlorite. The small amount of olivine originally present in the rock is now altered to serpentine and chlorite. Besides the chlorite, which is the chief alteration product, resulting from the plagioclase as well as from the augite and olivine, much secondary calcite has been derived from the feldspar. Apatite is found and titaniferous magnetite, in grains and definite crystals, is abundant. The medium texture of the diabase is fairly uniform throughout the flow.

OTHER IGNEOUS ROCKS

Other igneous rocks of petrographic interest, besides the above, are boulders of augite-andesite, diabase, melanite, phonolite, and tinguaite, which occur east of Livingston range and in the river drift along the North Fork of the Flathead river. Of these only the diabase could be traced to its source. It is found as an intrusive sheet 50 feet in thickness along the bed of Trail creek, about 4 miles west of the Great plains in British Columbia, where it had been seen previously by Dawson. Notable amounts of greenish plagioclase, radiating in star-like or more complex aggregates from one or more common central points, are found in it.

DIABASE AND ANDESITE BOULDERS

This diabase and pieces of andesite make up a large part of the igneous rocks in the North Fork river drift. Much more rarely phonolite and tinguaite are found. The first of these carries the black titaniferous garnet melanite. The mineral is distinctly recognizable, with orthoclase feldspars, at times nearly three-fourths of an inch long, in the hand specimen. The microscope reveals a holocrystalline porphyritic structure. Nephelite, which amounts to perhaps 25 per cent of the rock, is seen to be responsible for the greasy appearance in the hand specimen. With it in the groundmass twinned orthoclase is found in a second generation. Of unusual interest as being abnormal are the phenocrysts of apple-green hornblende, recognizable by the cleavage pattern on basal sections, which make up about 10 per cent of the rock. Orthoclase occurs, with the abundant large crystals of garnet, and almost as commonly observed six-sided pieces of nosean.

TINGUAITE BOULDERS

The tinguaite has likewise a porphyritic texture. The orthoclase feldspars are so abundant as to make up 40 per cent of the rock. They attain a maximum size of 2 centimeters by 5 centimeters, and commonly give rectangular cross-sections. They are set in a dull green groundmass, with here and there inconspicuous darker spots, where ægirine appears in small phenocrysts. Seen by transmitted light, they are a bright emerald green. Under the microscope the groundmass resolves itself into a matted aggregate of ægirine needles and sanidine, with small amounts of nephelite. The tinguaite was found near the mouth of Coal creek, but no indications of the rock were met at a distance from the North fork of Flathead river.

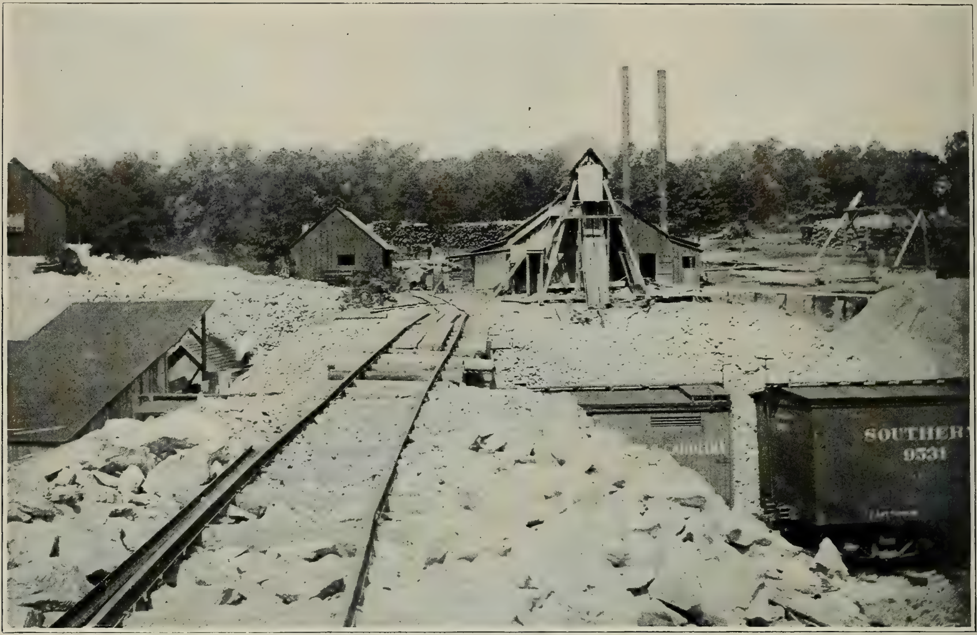

FIGURE 1.—HOLLOWAY MINE

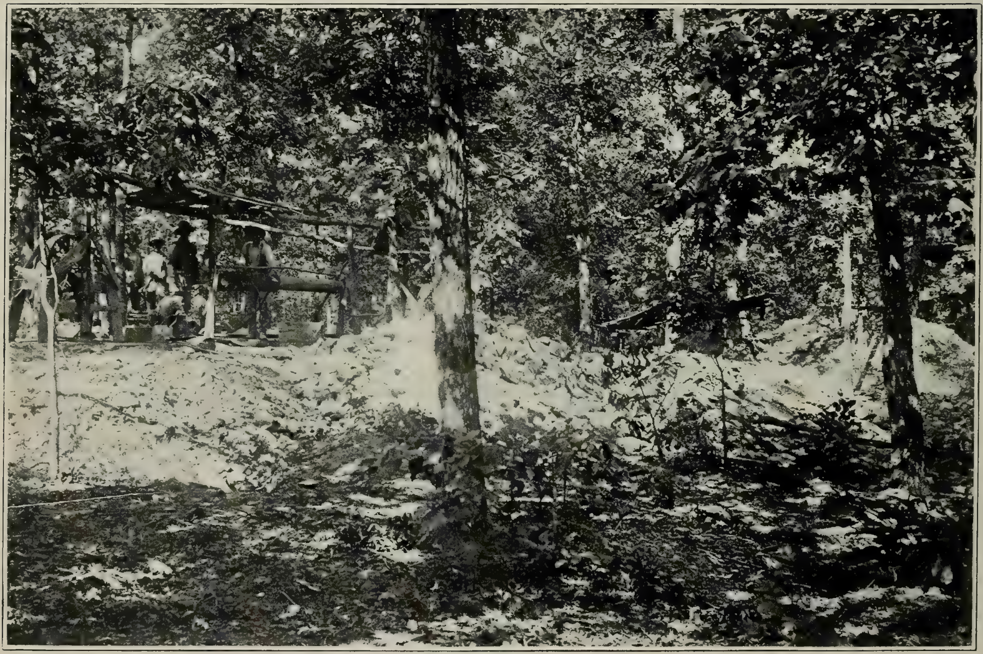

FIGURE 2.—SHAFT NUMBER 2—WALKER MINE

COPPER MINES, PERSON COUNTY, NORTH CAROLINA

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 13, PP. 353-376, PLS. 54-56 NOVEMBER 18, 1902

COPPER-BEARING ROCKS OF VIRGILINA COPPER DISTRICT, VIRGINIA AND NORTH CAROLINA *

BY THOMAS LEONARD WATSON

(*Presented before the Society January 2, 1902*)

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INTRODUCTION

Some time was spent during the month of August, 1901, in a field examination of the Virgilina copper district, and the specimens of the rocks and ores collected were subsequently studied in the laboratory. Study was principally confined, both in the field and laboratory, to the rocks of the area, to determine their nature and origin. The ores were given only secondary consideration.

The rocks have been designated slates by the earlier workers, which, according to present usage, would imply a metamorphosed sediment.

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* The author is under special obligations to Professor J. Morgan Clements, of the University of Wisconsin, for kindly reading and criticising this paper in manuscript, and he is indebted to Mr W. H. Pannebaker, of Virgilina, for the photographs illustrating it.

In many instances the characteristic field appearance of the rocks is that of slate or schist, but in their altered phases they are shown, by structural, chemical, and petrographic evidence, to be igneous in origin. Their subsequent alteration developed a schistose structure and an abundance of chlorite, epidote, and a limited quantity of hornblende. These impart to the rock its uniform green color and give the popular name "greenstone."

Recent workers are agreed as to the igneous origin of these rocks, and in a recent paper discussing the type of metalliferous deposits of the area Weed * has correctly named the rocks.

Scattered areas of ancient volcanic acid and basic rocks are described by Williams † and Nitze ‡ immediately to the southwest of the Virgilina district. The rock areas are found in Orange, Chatham, Montgomery, Randolph, and Stanly counties, North Carolina. Nitze describes the basic rocks as being dark green in color, partly massive and partly schistose in structure, and perhaps pyroxenic and at times propylitic in mineral composition. I have not visited these areas, but the descriptions of the basic rocks denote similarity to the Virgilina greenstones.

This paper discusses the evidence for regarding the Virgilina area as one of greatly altered pre-Cambrian volcanic rocks, closely allied to similar areas of ancient volcanics distributed along the Atlantic coast from eastern Canada to Georgia, and certain altered basic rocks in the Lake Superior region. The time which the writer was able to give to this investigation was insufficient to map and define the exact limits of the area.

PREVIOUS WORK

The rocks of this immediate area have hitherto received but little attention. No detailed work with respect to the differentiation and classification of the rocks of the Virgilina district has yet been undertaken. Brief references of a general character dating as far back as the Emmons Survey (1856) are found in numerous reports on economic subjects issued by the North Carolina Geological Survey. Such references as bear directly on the area in question are here reviewed:

After describing the Gillis copper mine in Person county, North Carolina, the earliest discovered one in the belt, Doctor Emmons § refers to the rock as follows: "The rock immediately investing the mine is the altered slate belonging to the Taconic system." Emmons first thought the rock was talcose, but later regarded it as argillaceous.

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* Trans. Amer. Inst. Min. Engrs., 1901, vol. xxx, p. 453 et seq.

† Journal of Geology, 1894, vol. ii, pp. 1-31.

‡ Bulletin no. 3, N. C. Geol. Survey, 1896, pp. 37-43; Bulletin no. 10, ibid., 1897, pp. 15, 16.

§ Geology of the Midland Counties of North Carolina, 1856, p. 344.

Professor Kerr* makes no special mention of this individual area in his report on the geology of North Carolina, but in defining the "Huronian" rocks of the state he groups the area as the northernmost limit of a belt of Huronian rocks traversing the state in a northeast-southwest direction. Speaking in a general way of the rocks composing the Huronian belt, Kerr mentions the following types: "Quartzite, clay slates, gray, light-colored and drab and greenish." "At some points the quartzites are argillaceous, and at others a few miles west of Smithfield it approaches a fine conglomerate. The clay slates are occasionally slightly hydro-micaceous." He mentions dikes of diabase and dolerite as being common over parts of Granville county. Professor Kerr refers the rocks of certain parts of Granville and Person counties to the lower Laurentian. He mentions the "characteristic and prevalent rocks as being syenite, dolerite, greenstone, amphibolite, granite, porphyry and trachite."

In a geological map of North Carolina, accompanying a report by Kerr and Hanna in 1887, the Person-Granville county area is grouped as the northernmost part of the Huronian.† A section given at the bottom of the map, extending from the Tennessee line to Newberne, North Carolina, designates the rocks of the copper belt area as "Huronian slates."

Mr Hanna ‡ describes the copper belt in Person and Granville counties in detail from the standpoint of economic mineralogy. He designates the rocks as schists and slates, and regards them as decidedly chloritic rather than argillaceous, as described by Emmons. Hanna gives the following quotation from a report by Doctor Jackson:

> "The strata are occasionally disrupted by dikes; about half a mile from the Gillis, and dipping eastward to it, is a dike bearing N. 20 E., containing abundant sprigs and grains of disseminated native copper. Epidote occurs both in the trap rock and in the quartz, and in the slate strata near the dike, which seems to indicate that the trappean rock is of the same geological age as the quartz veins."

Mr Lewis § describes areas of medium fine and compact grain biotite granites, occurring immediately to the east of the copper belt proper, in Granville and adjoining eastern counties.

In his description of the iron ore deposits in the northwestern part of Granville county, Mr Nitze || makes the following reference to the rocks: "Geologically they [iron ores] occur in the crystalline slates

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* Geology of North Carolina, 1875, vol. i, pp. 123, 124, and 131.

† Map accompanying "Ores of North Carolina," 1888.

‡ Ores of North Carolina, 1888, p. 215.

§ Notes on Building and Ornamental Stones, First Biennial Report, N. C. Geol. Survey, 1893, p. 75.

|| Iron Ores of North Carolina, N. C. Geol. Survey, Bulletin no. 1, 1893, p. 47; Engineering and Mining Journal, 1892, vol. 53, p. 447.

and schists, . . . lying conformably between slate walls . . ." He further mentions small crystals of magnetite occurring in gray micaceous schist coated with malachite.

Nitze and Hanna* mention in "Gold Deposits of North Carolina" the principal copper mines in the copper belt, giving assays of the ores and describing in some detail the topography and general geologic features. They designate the rock as schist.

Pages 37 to 43 of the same report describe the occurrence of ancient acid volcanics found in the same belt, but directly southwest of the Virgilina area. The scattered areas lie principally in Chatham and Orange counties, within short distances of Raleigh and Chapel Hill. The close resemblance of certain ones in structure and composition to the rhyolites of South Mountain in Pennsylvania is noted. The localities were visited by Professor George H. Williams, in company with Professor J. A. Holmes, in the summer of 1893, and afterward discussed in the Journal of Geology for 1894 by Williams.† They are referred to as pre-Cambrian in age, and are suggested as probably being contemporaneous with the somewhat analogous rocks of the South mountain, in Maryland and Pennsylvania.

In describing the Carolina Gold Belt area, situated in the central Piedmont region and crossing the central part of the state in a southwesterly direction, Nitze and Wilkens ‡ again refer to the kinds and distribution of the ancient volcanic rocks. Their description follows: §

> "The volcanic rocks occupy irregular patches along the eastern border of the belt, in close proximity to the western edges of the Jura-Trias basins. They comprise both acid and basic types. The acid rocks are generally devitrified to such an extent that their real character is no longer recognizable to the naked eye, and they appear as ordinary cherts or hornstones, although flow structure is at times still discernible. Microscopic examination shows them to belong to the class of rhyolites and quartz porphyries. They are sometimes sheared into schists, as for instance at the Haile mine, South Carolina. The basic types are dark green in color and perhaps pyroxenic in composition; they are sometimes massive porphyrites, but more generally sheared into schists. The pyroclastic breccias consist of angular fragments of the acid rhyolites and porphyries in a basic matrix. The age of these ancient volcanics is believed to be pre-Cambrian. They seem to be analogous to, and probably contemporaneous with, similar rocks of the South mountain in Maryland and Pennsylvania, and other points along the Atlantic coast."

Professor George H. Williams || published in 1894 a very important

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* Gold Deposits of North Carolina, N. C. Geol. Survey, Bulletin no. 3, 1896, p. 52.

† Journal of Geology, 1894, vol. ii, pp. 1–31.

‡ Gold Mining in North Carolina, et cetera, N. C. Geol. Survey, Bulletin No. 10, 1897, pp. 15, 16.

§ Ibid., p. 16.

|| Journal of Geology, 1894, vol. ii, pp. 1–31.

paper on the distribution of the ancient volcanic rocks along the Atlantic Coast region. Attention is directed in the paper to the area immediately southwest of the Virgilina district, in which occur both acid and basic eruptives, mostly acid, of pre-Cambrian age.

Mr W. H. Weed * recently published a valuable paper treating in some detail the type of ore deposits in this belt and the important economic features. He refers to the rocks of the district as follows:

> "The country-rock is schist, in few places massive enough to be called gneiss. . . . The rocks are all of igneous origin—even the softest and most shaly show this character in thin sections under the microscope. But in a few instances only is the igneous nature of the schists recognizable to the eye. This was observed at the Thomas mine, where a purplish rock is clearly a porphyritic meta-andesite. These schists are cut by dikes of later igneous rock (diabase). The only one seen by the writer was that exposed in the Blue Wing mine; . . . Apart from the dikes, however, I would say, on the strength of field-observations alone, that the rocks are of igneous origin, and belong to the various porphyries which have been discovered in the Appalachian belt. This conclusion is confirmed by the microscopic examination of thin sections, which has shown the rocks to be altered andesites, that is meta-andesites and andesite tuffs."

GENERAL FIELD CHARACTERS AND OCCURRENCE

As seen from the accompanying map, the area is located near the eastern border of the Piedmont plain, in Halifax county, Virginia, and Person and Granville counties, in North Carolina, 47 miles east of Danville. The belt occupies a low, flat-topped, though somewhat conspicuous, ridge, which trends a few degrees west of south and slopes very gradually both to the east and west. It will average 100 to 200 feet in elevation above the neighboring stream valleys. The cross-drainages are all small, but the ridge is flanked by several large ones on the west and northwest sides. The ridge is traced northward to the Dan River valley, in Virginia, some 10 miles north of the state line. In North Carolina its southward extension is estimated by Hanna † to be about 30 miles, reaching nearly to Durham. Prospecting is confined, however, to an approximate north-south distance of 18 miles along the ridge and to an average cross-distance of from 2 to 3 miles. Although of no conspicuous height, the ridge forms a somewhat prominent feature in the landscape.

Natural outcrops of the rock are by no means common and are seldom more than 3 feet high, forming sharp and narrow spurs or reefs, which persist for only short distances. The numerous shafts sunk over the

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* Types of Copper Deposits in the Southern United States, Trans. Amer. Inst. Min. Engrs., 1901, vol. xxx, pp. 453, 454.

† Ores of North Carolina, Raleigh, 1888, p. 215.

greater part of the belt to depths of 40 to 500 feet afford excellent opportunity for exceptional collections of the rocks and ores.

The covering of loose, decayed surface rock and soil is very thin, and the moderately fresh and firm rock is encountered at slight depths beneath the surface.

At the mine openings some alteration in the vein constituents is indicated to the entire depth of the workings, 400 to 500 feet. This is shown in the case of the sulphide ores, which in several places are slightly changed by the percolating carbonated waters to the green copper carbonate (malachite) found slightly staining the vein material and the unaltered ores. The rocks taken at these depths are of the same characteristic green color, and the thin-sections indicate the same amounts

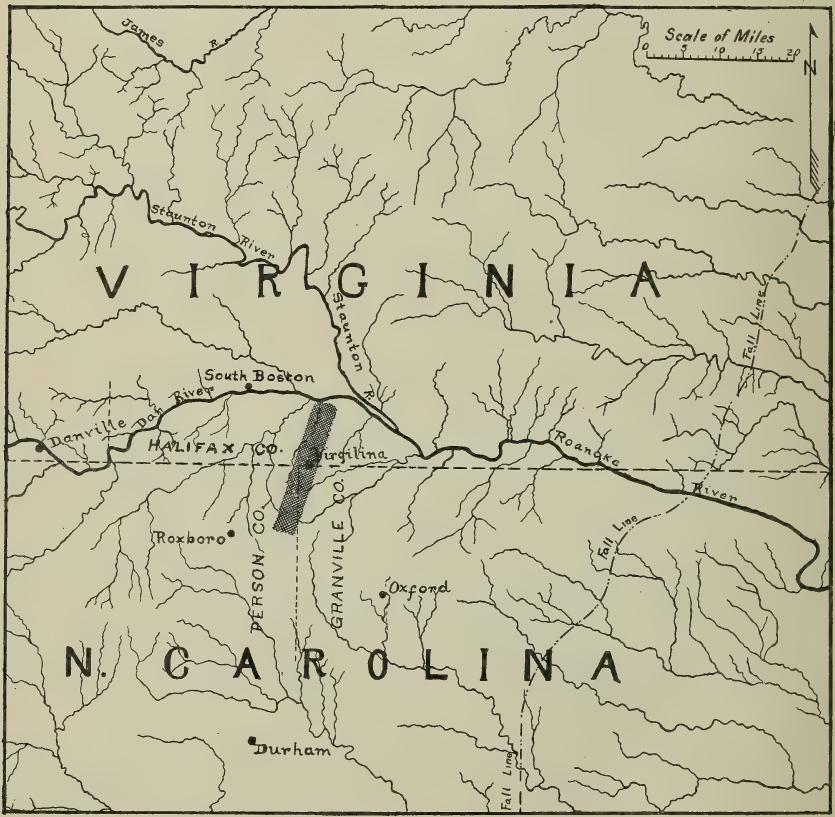
James R.
Scale of Miles
0 5 10 15 20
N
Staunton River
VIRGINIA
Staunton R.
South Boston
Dan River
Danville
HALIFAX CO.
Virgilina
Roanoke River
Fall Line
Fall Line
Roxboro
PERSON CO.
GRANVILLE CO.
Oxford
N. CAROLINA
Durham
Fall Line

FIGURE 1.—*Virgilina Copper District, Virginia and North Carolina*

Copper district indicated by shaded area

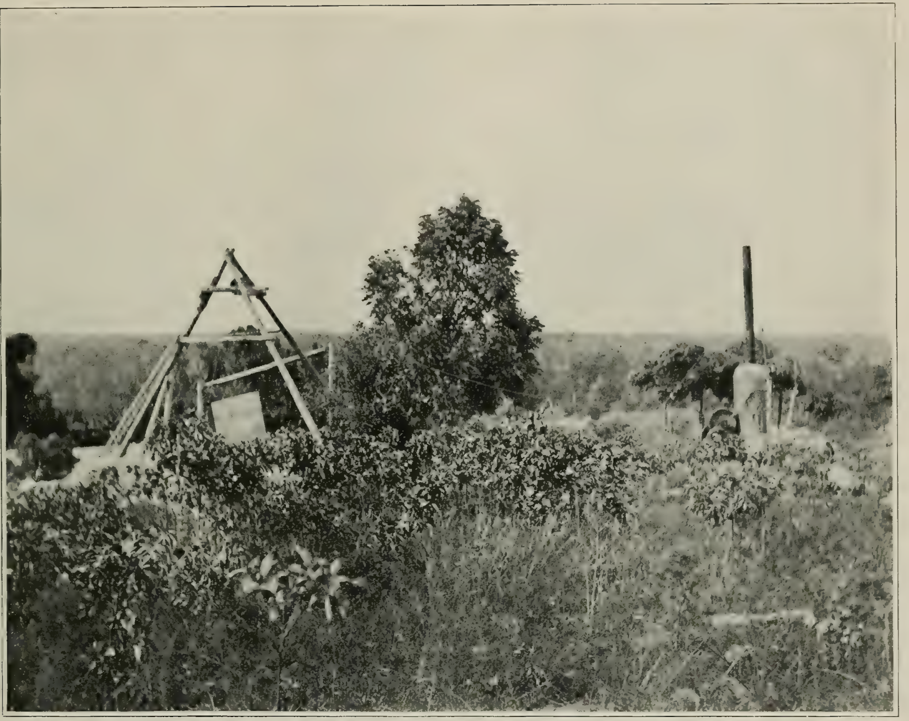

Figure 1.—Shaft Number 3

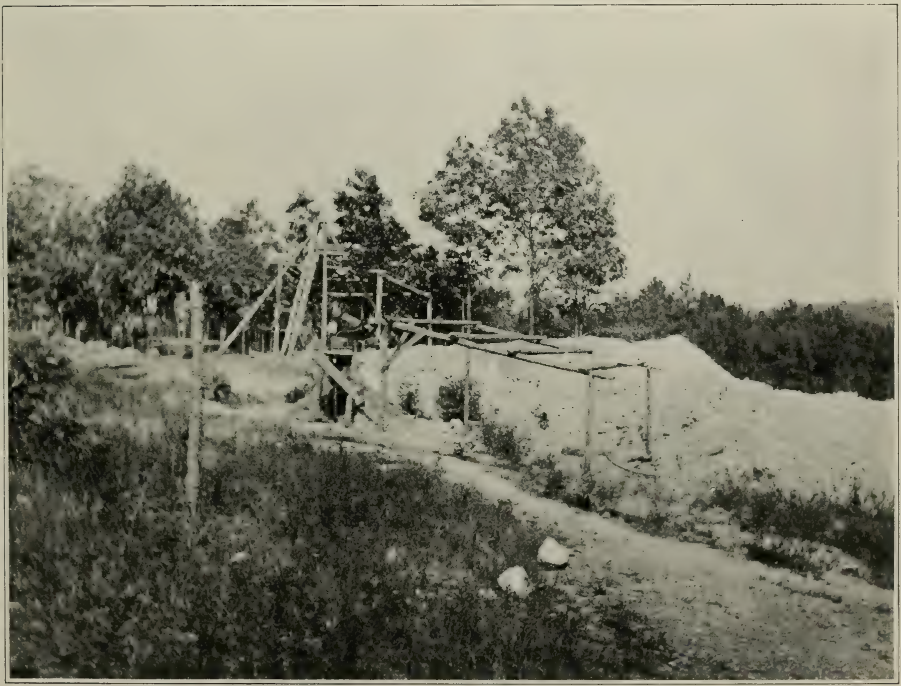

Figure 2.—Shaft Number 4

HIGH HILL COPPER MINES, HALIFAX COUNTY, VIRGINIA

of chlorite and epidote as those from the shallow depths. As developed, both macroscopically and microscopically, the rocks collected at the various depths are indistinguishable. This is also shown in the dumps at the mine openings.

The microscope reveals, as elsewhere shown, the igneous origin of the rocks; but, with few exceptions, the rocks do not entirely indicate their true igneous nature in the field. They are prevailingly finely laminated and schistose in structure, having the general characteristic features of a soft, green to purple colored schist. A number of sections showed the prevailing strike of the schistosity to be north 10 to 20 degrees east and an eastward dip of 70 to 80 degrees.

The change in these rocks is clearly the result primarily of the processes of metamorphism active while the rocks were deeply buried. At a subsequent date, when the rocks were brought near the surface, they were further changed by weathering. The mineral products resulting from the alteration are strongly in evidence. Epidotization and chloritization are manifested on a considerable scale.

The greenstones are cut in several places by diabase dikes of later geological age. One of these dikes, 12 feet wide, is exposed in the Blue Wing mine at the 100-foot level, where it is observed to cut across the schistosity of the rocks. These dikes are described in the reports of the North Carolina Survey as being quite numerous in parts of Granville and Person counties. Faulted and slickensided surfaces are in evidence at some of the mine openings.

The rocks are further cut by numerous irregular quartz veins, which contain the workable copper ores. The veins are traced for a mile or more in length on the surface, and in most cases they are more or less parallel, partially overlapping at the ends, and trending north 5 to 10 degrees east. They are grouped by Weed* as true fissure veins, lenticular in shape, though connecting, crossing at times the schistosity of the rocks and at others parallel to it. The surface over most of the district is much littered with white quartz fragments derived from the disintegration of the veins.

PETROGRAPHY

MACROSCOPIC DESCRIPTIONS

A pronounced schistose structure prevails, and only in a few places do the rocks appear like massive eruptives in the field. The degree of schistosity varies from the thin banding of a gneiss to the typical foliation of micaceous schists. The very finely banded structure is more characteristic of the purple-colored rocks. The rocks vary in color from some shade of medium to dark green (the prevailing color) to a slate purple.

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*Trans. Amer. Inst. Min. Engrs., 1901, vol. xxx, p. 452.

The rocks are aphanitic in texture, displaying at times a distinct porphyritic structure in the massive phases, which becomes more apparent under the microscope. The massive phases of the rock are indicated at several places within a few miles to the north and south of the town of Virgilina. With one exception, this type is prevailingly dark in color, showing on close examination a mingling of green and purplish shades, with the greenish tint so predominant that the rock appears dark green on first glance. Both the characteristic chlorite and epidote shades of green are contrasted at times in the same specimen. On a freshly broken surface the fracture is conchoidal to subconchoidal, with a more or less waxy luster.

Approximately half a mile south of Virgilina a shallow opening (Cornfield) is made, showing the massive rock in its least altered condition (analysis I). The rock is porphyritic in structure and the color is a medium dark-purplish shade, which contrasts with the surrounding more altered green schistose rock.

Epidote of the usual pistachio-green color enters largely in places into the composition of the rocks, and it is mixed locally in considerable proportion with white quartz as a vein mineral. The schistose greenstone is easily scratched with the knife, and suggests approximately the same degree of hardness as that of ordinary clay slate.

At the Copper World mine, 6½ miles south of Virgilina, in the Carolina portion of the belt, a partially loose-textured, fine-grained, purple rock is mixed with the surrounding green schists. The material bears every resemblance to a tuff,* and is streaked in places by the characteristic actinolite shade of green due to alteration, and contains inclosures of a dark-colored massive material, usually of small but varying dimensions and partially rounded in outline. The fragmental or clastic nature of the mass is plainly visible. The microscope confirms the clastic nature of this rock and shows that it is composed of fragments of igneous rocks of the same character and composition as the igneous rocks of the district. Microscopic study also indicates the presence of similar clastic material at a number of other points in the district.

No trace of the amygdaloidal structure, so characteristic of the South Mountain and Lake Superior basic greenstone areas, has been observed in the Virgilina rock.

MICROSCOPY OF THE ROCKS

The rocks vary in texture from dense aphanitic to medium fine-grained, with the porphyritic structure shown usually in the massive types. The original minerals are entirely altered to secondary minerals in many of the sections, but, with few exceptions, some trace of the original outline of the feldspar constituent is shown and more or less of the original rock texture preserved. While this is true for the feldspar constituent, the original bisilicate constituent is completely altered in every slide studied, without any indication as to what the mineral originally was. Considering the age and composition of the rocks, it seems remarkable that any of the original minerals or structures should be preserved at present. When shown, the texture varies from a partial microophitic to microlitic in the non-porphyritic types, with the same variation and composition of the groundmass in the porphyritic rocks denoted.

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*See Weed, W. H., op. cit.

The constituents present are plagioclase, bluish to light green amphibole, chlorite, epidote, zoisite, calcite, iron oxide (partly magnetite), quartz, and apatite. Of these only the feldspar, a part of the iron oxide (magnetite), and apatite are original. Both chlorite and epidote, intimately associated with more or less hornblende, are abundantly developed in most of the sections, sometimes one, sometimes the other predominating; but the two are at all times intimately connected.

In the porphyritic and non-porphyritic types the feldspar is present as lath-shaped crystals, showing the broad twinning lamellæ of the albite type. Twinning after the Carlsbad law was observed in several instances. In the groundmass of the porphyritic rocks and in the fine-textured non-porphyritic types the feldspars are microlitic, with the boundaries less sharp and well defined than for the lath-shaped feldspars, and the twinning is not at all or only slightly indicated. Sometimes the feldspar grouping is suggestive of the sheaf-like arrangement described by Clements * in similar volcanic rocks of the Hemlock formation of lake Superior. Poikilitic texture is well developed in many of the larger feldspar laths.

Feldspar is the only porphyritically developed mineral, and it consists of fairly large, stout laths of broadly striated plagioclase, with maximum extinction angles measured on the twinning planes of 14 to 20 degrees, which would apparently indicate an acid plagioclase, probably near oligoclase.

The feldspars of both the groundmass and phenocrysts are frequently fractured and mashed, showing the effects of pressure, which is seen to best advantage in the schistose rocks.

Not a trace of original hornblende was positively identified in any of the sections. Amphibole is fairly abundant in most of the slides as a secondary product, and as such is usually light green to slight bluish

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* Monograph no. xxxvi, U. S. Geol. Survey, 1899, p. 99.

green in color and as fibrous and frayed-out masses. A more common occurrence, perhaps, is as a felt of actinolite needles admixed with the other constituents, particularly chlorite, epidote, and iron oxide. The needles are very long and slender and are frequently much curved and bent. The pleochroism of the actinolite is usually quite strong.

No trace of either augite or olivine was indicated in any of the slides. On account of the greatly altered condition of the rocks, it would not be safe to state that they were not present as original constituents.

Chlorite is a constant and abundant constituent of the rocks, but is variable in amount, and presents the usual occurrence for such rocks. A striking feature is the intimately associated grains and plates of epidote distributed through the chloritic mass in a manner to indicate the simultaneous development of the two minerals, a characteristic occurrence in some of the Lake Superior greenstones described by Williams.* Clements † has shown that in some of the basic volcanics of the Hemlock formation the great abundance of chlorite in some sections is more than could result from the alteration of that amount of the original bisilicate present, and points out that it is derived in part from the altered glassy base. This explanation is likely applicable to some of the sections of the Virgilina rocks, since the amount of chlorite is in excess of the original bisilicate, and is probably a derived product in part from an altered glassy base.

Epidote in the form of small and large irregular grains and plates is abundantly present, closely associated with the chlorite and amphibole. It varies in color from deep yellow to nearly colorless grains, with high single and double refraction, and showing strong pleochroism in the colored individuals. The somewhat idiomorphic plates show the M(001) and T(100) cleavages in their usual development.

Zoisite, when identified, was closely intergrown with the epidote, forming an epidote-zoisite aggregate, the individuals of which are differentiated by their contrasted double refraction.

Iron oxide is extremely abundant in portions of some of the sections, and to some degree in all. It is not all magnetite, as indicated by the red color of much of it. It is separated from the other constituents of the powdered rock by means of the magnet. It occurs as minute grains and crystals, and is in part primary and in part secondary. It is so abundant in some sections as to entirely mask some of the other more important constituents. Its secondary nature is frequently shown in its peripheral position surrounding the iron-bearing constituent from which it was derived.

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* Bulletin no. 62, U. S. Geol. Survey, 1890, p. 56 et seq.
† Monograph no. xxxvi, U. S. Geol. Survey, 1899, p. 101.

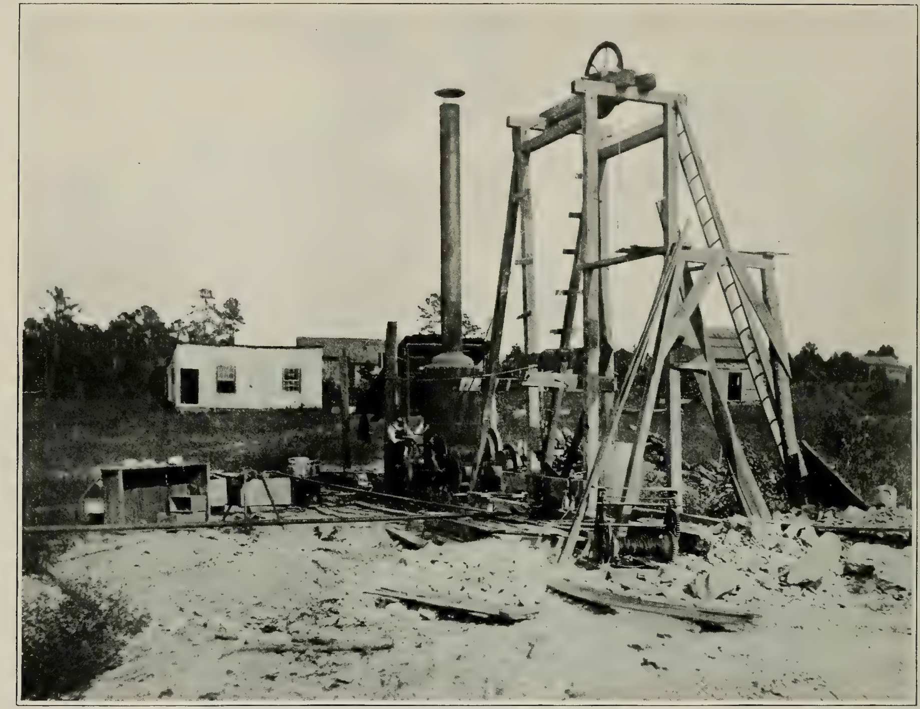

Figure 1.—Shaft Number 1—Yancey Mine

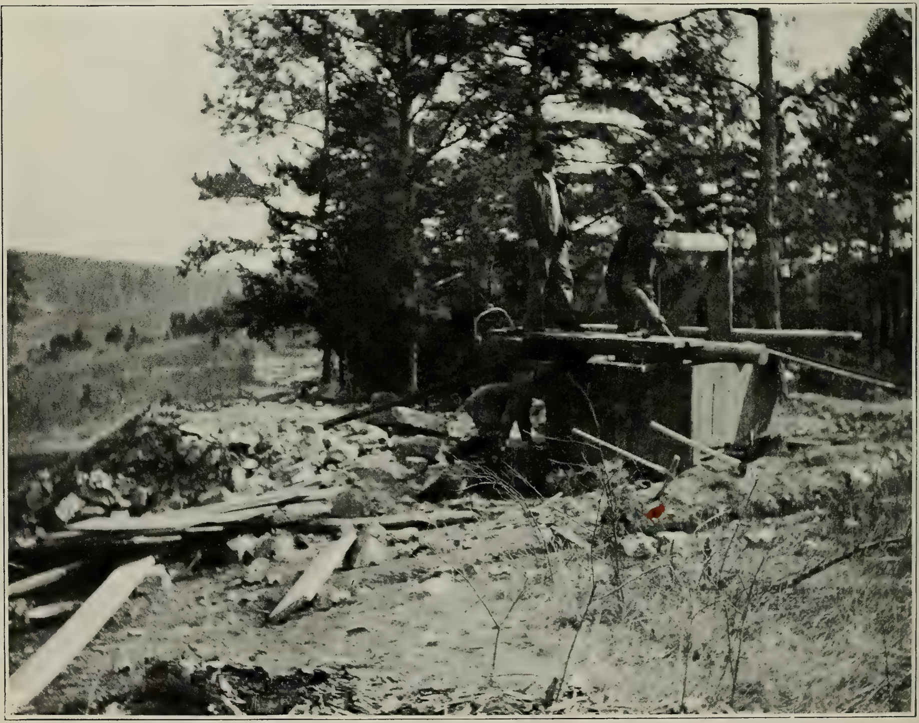

Figure 2.—Fourth of July Shaft

COPPER MINES, PERSON COUNTY, NORTH CAROLINA

The remaining minerals occurring in the rocks present no noteworthy features.

In the thin-sections of the purple-colored slaty rocks of the Copper World, Durgy, and Yancey mines and the "Slate Vein," in the Carolina portion of the belt, and probably the fissile greenstone from the Halifax Copper mine, in Virginia, there is strong evidence for regarding the rocks as clastic volcanics. The evidence is less plain in some sections than in others, on account of the extreme alteration having destroyed nearly all trace of the rock structure. When the texture is not entirely destroyed the microscope shows a clastic composed of igneous fragments similar in all respects to the true igneous rocks of the district.*

The clastic nature of the rock at the Copper World mine is visible to the unaided eye and is described elsewhere in this paper. At no other point in the belt was the writer able to detect with certainty the clastic nature of any part of the volcanics.

The microscopic study entirely fails to indicate what the original characterizing bisilicate component was in these rocks—whether augite or hornblende, or both, with possible biotite and olivine. We are in doubt, therefore, as to whether the rocks were originally augite or hornblende andesites.

Chemical Analyses

Six analyses of the Virgilina greenstones, four complete (analyses I–V, inclusive) and two partial (VI and VII), were made by the writer in the chemical laboratory of Denison University.† These are compared with analyses of so-called greenstones (Catoctin schist) of the Catoctin belt of northern Virginia (analysis VIII) and with those of the well known Marquette and Negaunee districts of Michigan (analyses XIII and XIV). Also analyses I and II, representing the freshest material, are compared with analyses of andesites from Colorado (analyses IX and XII) and Maine (analysis XI).

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* Through the kindness of Professor J. Morgan Clements, of the University of Wisconsin, I have been able to examine and compare the slides of the similar volcanic rocks of the Lake Superior region, and the similarity, as remarked by Professor Clements, is strikingly close to the rocks of the Virgilina district.

Professor Clements very kindly examined the thin-sections of the Virginia-North Carolina rocks and the accompanying hand specimens here described, and in a personal memorandum to the writer stated that the rocks were igneous and of an andesitic character, confirming the writer's study of the material; further, that the evidence was strong for regarding some of the volcanics as clastics composed of fragments of basic or intermediate igneous rocks similar to the igneous rocks of the district. He says: "I find they [Virginia-North Carolina rocks] are very similar to the greenstones which form so important a part of the Archæan and Algonkian of the Lake Superior region."

† I am indebted to Professor W. Blair Clark, of Denison University, for kindly placing at my disposal the facilities for making the analyses.

	I.	II.	III.	IV.	V.	VI.	VII.
SiO_2	64.12	62.32	63.22	51.34	48.20	46.45	49.51
TiO_2	Trace.	0.06	0.03	0.38	0.24	Trace.	0.57
Al_2O_3	16.32	15.79	16.05	20.07	22.10	13.79	22.42
Fe_2O_3	6.72	3.57	5.15	7.03	7.61	7.60	10.03
FeO	1.38	4.61	2.49	4.03	3.95	6.41	2.42
MnO	0.64	0.35	0.49	0.38	0.35	Trace.	0.42
CaO	3.49	3.65	3.57	2.83	8.86	10.13	7.68
MgO	0.33	2.53	1.43	4.18	0.86	9.81	2.81
BaO	....	....	....	....	....	....	....
SrO	....	....	....	....	....	....	....
Na_2O	6.22	4.51	5.37	1.83	4.90	Undet.	Undet.
K_2O	0.53	0.76	0.64	5.53	1.16		
Li_2O	....	....	....	....	....	....	....
H_2O	0.34	1.89	1.11	2.90	2.31	2.66	3.41
P_2O_5	Undet.	Undet.	Undet.	Undet.	Undet.	Undet.	Undet.
SO_3	....	....	....	....	....	....	....
CO_2	None.	None.	None.	None.	None.	2.27	0.90
V_2O_3	....	....	....	....	....	....	....
	100.09	100.04	99.55	100.50	100.54	....	....

I. Andesite, dark purplish gray, massive and slightly porphyritic in texture, 0.5 mile south of Virgilina, Granville county, North Carolina; Cornfield opening. Analysis by Thomas L. Watson.

II. Dark massive greenstone; Overby opening. Analysis by Thomas L. Watson.

III. Average of I and II.

IV. Bright schistose greenstone, Blue Wing mine, 3 miles south of Virgilina, Granville county, North Carolina. Analysis by Thomas L. Watson.

V. Bright schistose greenstone, Fourth of July mine, 2.5 miles south of Virgilina, Granville county, North Carolina. Analysis by Thomas L. Watson.

VI. Bright schistose greenstone, Anaconda mine, 1.5 miles north of Virgilina, Halifax county, Virginia. Analysis by Thomas L. Watson.

VII. Partially decayed schistose greenstone from same locality as VI. Analysis by Thomas L. Watson.

VIII. Andesite, 3.5 miles east of Front Royal, Virginia. Analysis by George Steiger, Bulletin 168, U. S. Geological Survey, 1900, page 51; described by Keith, Fourteenth Annual Report, U. S. Geological Survey, page 305.

IX. Hornblende andesite, summit of southeast spur of Galena mountain, above Big 10 claim, near Silverton, Colorado. Frank R. Van Horn, Bulletin of the Geological Society of America, 1900, volume 12, page 8.

ANALYSES

VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.
51.08	61.36	61.40	61.45	61.58	43.80	44.49	50.20	61.37
2.67	Undet.	0.79	2.80	0.49	Undet.	Undet.	....	0.60
11.37	16.56	16.59	15.07	16.96	16.08	16.37	15.43	15.41
11.17	3.44	2.13	4.46	1.75	9.47	5.07	....	3.15
5.64	2.93	3.05	1.18	2.85	10.50	5.50	13.79	3.89
0.22	Undet.	0.13	None.	Trace.	....	....	....	0.47
5.20	4.56	6.17	5.37	6.28	7.81	7.94	5.47	4.42
3.96	0.85	2.73	3.02	3.67	6.54	7.50	8.62	3.48
....	....	0.02	....	0.03	....	....	....	0.08
....	....	Trace?	....	Trace.	....	....	....	Trace.
{ 5.54	6.86	3.83	4.00	3.94	1.96	2.59	4.75	3.76
{ 1.50	1.30	1.34	1.22	1.28	0.34	0.56	....	0.34
....	....	Trace.	0.05	Trace.	....	....	....	....
1.50	1.55	1.70	1.23	1.30	3.99	4.99	1.74	2.99
....	....	0.20	Trace.	0.22	....	....	....	0.08
....	....	....	0.29	....	....	....	....	....
0.39	Trace.	None.	....	....	0.08	5.38	....	....
....	....	0.02	....	....	....	....	....	....
100.24	99.41	100.10	100.14	100.35	100.57	100.39	100.00	100.04

X. Andesite, Edmund's Hill, Aroostook county, Maine. Analysis by W. F. Hillebrand. Herbert E. Gregory, American Journal of Science, 1899, volume viii, page 365.

XI. Pyroxene andesite, Agate creek, Yellowstone National park. Analysis by Whitfield, Bulletin 168, U. S. Geological Survey, 1900, page 108.

XII. Hornblende andesite, mount Shasta, California. Analysis by H. N. Stokes, Bulletin 168, U. S. Geological Survey, 1900, page 176.

XIII. Dark massive greenstone, Lower Quinnesec falls, Michigan. Analysis by R. B. Riggs. G. H. Williams, Bulletin 62, U. S. Geological Survey, 1890, page 91.

XIV. Dark schistose greenstone, forming a band in XIII. Analysis by R. B. Riggs. G. H. Williams, Bulletin 62, U. S. Geological Survey, 1890, page 91.

XV. Greenstone, summit of ridge at Cliff mine. Quoted by A. C. Lane, Geological Report on Isle Royale, Michigan, Geological Survey of Michigan, 1893–1897, volume vi, page 215.

XVI. Meta-andesite, 1.5 miles northward from Jenny Lind. Analysis by W. F. Hillebrand. Bulletin 168, U. S. Geological Survey, 1900, page 203.

A cursory examination of the analyses is sufficient to indicate the andesitic character of the rocks, with an advanced stage of alteration shown in IV, V, VI, and VII. Furthermore, the ratio of the SiO_2 to the base-forming elements in I and II, the least altered material, suggests an intermediate rather than an acid or basic andesite. The prevailingly low SiO_2 in the remaining analyses (IV, V, VI, and VII) is explained on the basis of advanced alteration, since the rocks yielding these results were the most altered and were highly schistose in structure. Other apparent irregularities in the analyses are likewise explained on the same basis, since the greatest irregularities are indicated in the analyses of the most altered specimens. To what extent the ore-bearing solutions have aided in the alteration it is not possible to say, but that the change has resulted in part from such action is doubtless shown in the metalliferous veins of the district.

When I, II, and III, analyses of the least altered rock, are compared with analyses of recognized andesites occurring elsewhere, no marked differences in the essential constituents are shown.

Higher SiO_2 and Al_2O_3 and lower Fe_2O_3, FeO, CaO, and MgO in the Virgilina rocks than for the similar rocks in the Catoctin belt are noted. Na_2O is approximately the same for the two rocks, with increased K_2O shown in the Catoctin andesite. The Catoctin andesite is characterized by very high iron oxide and correspondingly low SiO_2 and clearly represents the basic type of andesite, which readily accounts for the apparent variations shown in the comparison with the Virgilina rock.

Comparing the analyses of the Virginia-North Carolina rocks with those of andesites from Colorado (analyses IX, XI, and XII) and Maine (analysis X), the differences are by no means so great as shown in the Catoctin andesite, but, on the contrary, the figures are strikingly close and uniform for rocks occurring in areas so widely separated.

Analyses XIII and XIV are of typical greenstones from the Michigan area derived, as Williams states, from the igneous rock type, diabase. A comparison of these two analyses with the average of I and II given in column III indicates at a glance those differences shown in chemical composition which distinguish a diabase from an andesite.

So far, then, as chemical analyses are trustworthy, the percentage ratios of the various constituents in the Virginia-North Carolina rocks, as indicated in I and II, and their average III, are those of andesite. Passing, then, from the least to the most altered phases of the rocks, the change is observed to consist largely in the increase in the amount of chlorite, as clearly manifested in the assumption of water, hydration; and also in increased Al_2O_3, FeO, and MgO. A similar change in the rocks of the greenstone area of Michigan has been emphasized by Williams. A second and no less important change in the Virginia-North Carolina rocks is the increased amount of epidote in the much-altered phases of the rocks, a fact indicated microscopically as well as in the field, and further confirmed chemically in the greatly increased amounts of CaO in the analyses of the altered over those of the fresher rocks.

Attention is finally directed to the alkalies' ratio in these rocks, in which it is observed that K_2O is reduced to practically a minimum, while the Na_2O is proportionately increased. The constant presence of TiO_2 and MnO in the analyses is a noteworthy feature.

EVIDENCES OF ERUPTIVE CHARACTER

FIELD EVIDENCE

The field evidence that the schistose rocks here studied are of igneous origin is not entirely lacking when the belt as a whole is considered. While the rocks are prevailingly schistose or foliated, and in places thinly fissile, areas of much altered, though massive, rocks of the same color and texture are met in a number of places, and are most satisfactorily explained as igneous in origin. This alteration is the result of dynamic metamorphism accompanied by much chemical action, consisting largely in the abundant development of chlorite and epidote. A similar change has been observed in the greenstone areas of Michigan[*] and South mountain,[†] Pennsylvania. In most cases where the original character is entirely lost and a perfect secondary schistosity assumed it becomes necessary to resort to the microscope to determine their nature.

In the massive and least altered phases of the rock the porphyritic structure is apparent. The porphyritic constituent measures less than one millimeter in size, and is distributed through an aphanitic groundmass of uniformly green and purple colors. The porphyritic structure is more strikingly shown in some of the thin-sections under the microscope than in the hand specimens. In such cases the porphyritic mineral consists principally of a well striated plagioclase.

The prevailing fineness of grain of these rocks, which is equally characteristic of the freshest specimens as for the most altered material, and the associated tuffs or clastic volcanics suggests solidification at the surface.

The weathered outcrops afford, as a rule, only slight indication of an igneous mass, although at one point a few miles to the south of Virgilina, in Carolina, the spheroidal type of weathering was observed.

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[*] Williams, G. H., Bulletin no. 62, U. S. Geol. Survey, 1890, pp. 192–217.

[†] Bascom, F., Bulletin no. 136, U. S. Geol. Survey, 1896, p. 25.

Since the rocks are usually no longer massive, but instead are highly schistose in structure, the weathered surfaces for structural reasons would be expected to more closely simulate those of sedimentary masses.

The extension of the belt as traced from the rock outcrops for many miles in an approximately north-south direction, with comparatively a very narrow cross-section, is certainly suggestive. Their weight, color, texture, and not unfrequent massive structure are properties more characteristic of igneous than of sedimentary rocks.

Massive granites and granitic gneisses, and in places dikes of diabase, limit the area on the east and west sides. In several instances the diabase is found cutting the rocks of the greenstone area. Some evidence, both field and microscopic, is at hand for regarding some of the rocks at several places in the belt as altered andesite tuffs or clastics composed of fragments of the igneous rock.* The study has not been sufficiently extended, however, if, indeed, it were possible, to differentiate the clastic volcanics (tuffs) from the direct igneous masses of the area.

MICROSCOPICAL EVIDENCE

The evidence of the igneous origin of these rocks is not entirely that of field relations, but is derived largely from microscopic structure, mineral and chemical composition. In many instances the thin-sections show both stout and acicular forms of striated feldspar partially or wholly preserved, embedded in a fine-grained groundmass composed principally of green chlorite and hornblende, epidote, altered feldspar and iron oxide. This arrangement is not confined to the massive and least altered forms of the rocks, but is indicated to some degree in the partial skeleton outlines of some of the original minerals in several slides of the perfectly schistose rocks. In many cases chemical and structural metamorphism have progressed so far that all trace of the original structure, as well as that of every original mineral, has been destroyed.

The occurrence of lath-shaped polysynthetically twinned crystals of plagioclase which appears to have formed an essential constituent of the rocks is characteristic of rocks of igneous origin. Furthermore, the micro-ophitic and poikilitic structures of the feldspars of some of the rocks in thin-section under the microscope are common only to igneous masses. The structures bear certain striking resemblances to similar rocks of igneous origin described by Williams † and Clements ‡ from the Lake Superior region. Professor Williams § reproduces a photomicrograph of a thin-section of one of the rocks showing this structure from the Negaunee district, which has its analogue in several sections of the Virgilina rocks.

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* Weed, op. cit.

† Williams, G. H., Bulletin no. 62, U. S. Geol. Survey, 1890.

‡ Clements, J. Morgan, Jour. of Geology, 1895, vol. iii, pp. 801–822; Monograph, no. xxxvi, U. S. Geol. Survey, pp. 98–103.

§ Williams, G. H., op. cit., p. 226, plate x, figure 2.

The minerals composing the rocks, which are chiefly secondary, are those which would result from chemical and structural metamorphism of an original igneous rock of basic or intermediate composition.

While, as already stated, in most instances all trace of the original minerals in the rocks is lost or destroyed, in some sections enough remains to tell with some degree of certainty what their original essential minerals were.

The analyses of these rocks given in the table on page — confirm their igneous character. When compared with similar analyses of well known igneous rocks of a certain type from widely separated localities, fairly close agreement is shown in the essential chemical features. Knowing, therefore, the greatly altered condition of the bulk of the rocks in the area, such differences as are brought out in the table of analyses are readily explained on the basis of chemical and physical metamorphism.

CHEMICAL EVIDENCE

The chemical analyses of these rocks have been previously discussed in this paper—pages 363–367. The close conformity in composition of the rocks (the least altered ones), as there indicated, with that of andesites from well known but widely separated localities is certainly indicative of igneous origin. Their uniform composition is in contrast with that of a series of clastic rocks, where, as shown by Rosenbusch,[*] the chemical proportions are largely accidental. The microscopical study fully confirms the chemical evidence favoring the igneous origin of these rocks.

COMPARISON WITH OTHER AREAS

Scattered areas of ancient volcanic rocks have been recognized at various localities along the Atlantic coast by geologists, extending from New Brunswick through Maine, New Hampshire, Massachusetts, Pennsylvania, and Maryland into northern Virginia, the Carolinas, Georgia[§] and Alabama. Some of the so-called sedimentary areas of the northern Atlantic coast of the earlier geologists are now regarded as altered volcanic rocks.

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[*] Zur Auffassung der Chemischen Natur des Grundgebirges, Tschermak's Min. u. Petrog. Mitth. 1891, vol. xii, pp. 49–61.

[†] G. H. Williams discusses the subject in the 15th Ann. Report, U. S. Geol. Survey, 1895, pp. 663–664.

[‡] For a statement of the distribution of the volcanic rocks on the Atlantic coast, see Williams, Jour. Geology, 1894, ii, 1–31.

Areas of such volcanics have been described from eastern Canada,* by Bailey, Matthew, Ells, and Bell. In New England † Wadsworth, Diller, Shaler, Bayley, G. O. Smith, H. S. Williams, and Gregory have described similar areas in Massachusetts and Maine. Other similar areas are well known in Pennsylvania, Maryland, and Virginia through the investigations of G. H. Williams, ‡ Keith, § and Bascom.‖ In the Lake Superior region¶ they have been long known through the contributions principally of Irving, Van Hise, the Winchells, Clements, Bayley, Wadsworth, Williams, and Grant.

Through the studies of Clements and Brooks areas of greenstone schists, similar to those of the Lake Superior region, and derived from an original basic igneous rock of pre-Cambrian age, have been identified in the crystalline area of Alabama.**

The rock types indicated in these areas vary from acid to basic volcanics in composition, according to locality, and are represented principally by such rocks as rhyolite, andesite, diabase, diorite, gabbro, and their associated tuff deposits.

From the descriptions, the rocks of the Virgilina district are closely similar in many essential features to the corresponding altered phases of the Catoctin and South Mountain areas in Virginia, Maryland, and Pennsylvania, and certain ones of the famous greenstones from the Lake Superior region. When the altered rocks, greenstones, of the various areas are traced by means of chemical and microscopical study to the original rock type, the differences become more apparent. This difference is that which distinguishes in the original rock an andesite from a diabase, diorite, gabbro, etcetera; but, as already stated, the altered rock derived from these several types is closely similar.

Sufficient study of the ancient volcanic rocks occurring to the southwest of the Virgilina area, in North Carolina, is lacking on which to base specific comparisons. That they are altered volcanic rocks of great age, comprising both acid and basic types, is established, but the exact mineral and chemical composition, denoting the original rock types from which they are derived, is yet to be investigated. Megascopic descriptions and the field relations of many of the basic types indicate their striking similarity to those of the Virgilina district.

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* Ann. Report Canadian Geol. Survey, 1877–'8 D D, 1879–'80 D, 1889–'90 F, 1891.

† Mus. Comp. Zool. Bull., vol. v, p. 282; ibid., vol. vii, pp. 166–187, 1881; A. J. S., 1886, vol. 32, p. 40; 8th Ann. Rept. U. S. G. S., pt. 2, p. 1043; A. J. S., 1899, vol. viii, p. 359; Bull. no. 165, U. S. G. S., 1900, 212 pp.

‡ A. J. S., 1892, xliv, 482–496; Jour. Geology, 1894, ii, 1–31.

§ 14th Ann. Rept. U. S. G. S., 1894, pp. 285-395; Am. Geol., 1892, x, 365; Bull. G. S. A., ii, 156, 163.

‖ Bull. no. 136, U. S. G. S., 1896, 124 pp.

¶ The literature is scattered through annual reports, monographs, and bulletins of the U. S. Geological Survey and the state reports of the surveys of Minnesota, Wisconsin, and Michigan.

** Geol. Survey of Alabama, Bulletin no. 5, 1896, pp. 84–96, 120–197.

As developed from the chemical and microscopic study of the rocks of the Virgilina district, the present much altered rock, greenstone, clearly indicates its derivation from an original andesite of an intermediate basic type as contrasted with the similar Catoctin schist or greenstone, which from Keith's * description, is derived from a more basic andesite, diabase, or basalt.

According to Keith, the rocks of the Catoctin area are igneous in origin and represent probably two different flows—the upper, basaltic, and the lower, dioritic. In general the rocks are much altered through dynamic metamorphism and secular decay and now largely form greenish epidotic and chloritic schists, designated by Keith as the Catoctin schist. The fine-grained varieties are composed of quartz, plagioclase, epidote, magnetite, and chlorite. In the coarse-grained types the original nature of the rock is well indicated. The ophitic arrangement of the coarse feldspars is definitely marked. The additional minerals in the coarse rocks are calcite, ilmenite, skeleton olivine, biotite, hematite, and, in a few instances, hornblende. The alteration products, chlorite and epidote, are abundant and characteristic. An analysis of the fresh rock by George Steiger is shown in column VIII of table of analyses, on pages 364–365.

The South Mountain area is shown by Williams † and Bascom ‡ to consist of the acid volcanic rhyolite and the basic types, diabase and basalt, the latter yielding on alteration the greenstones of the region. Bascom § further describes the basic types of this area as holocrystalline, effusive, plagioclase-augite rocks, with or without olivine, the essential characteristics of the diabase group.

After establishing the igneous origin of the greenstones of the Menominee and Marquette districts of Michigan, Williams || shows the different rock types to have been olivine-gabbro, gabbro, diabase, diabase-porphyry, glassy diabase and melaphyre, diorite, diorite-porphyry, and tuffs, with the two districts limited on their north and south sides by an acid series consisting of granite, granite-porphyry, and quartz-porphyry.

The original mineral constituents of these rocks are described by Williams ¶ as labradorite, quartz, biotite, hornblende, diallage, augite, olivine, zircon, apatite, sphene, ilmenite, and magnetite. The secondary minerals produced by metamorphism and weathering are albite, saussurite, zoisite, quartz, hornblende, epidote, chlorite, biotite, talc, serpentine, carbonates, iron oxides, and pyrite.**

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* 14th Ann. Rept. U. S. G. S., 1894, p. 304 et seq.

† Op. cit.

‡ Op. cit.

§ Ibid., p. 69.

|| Bull. U. S. Geol. Survey, no. 62, pp. 197–199.

¶ Ibid., pp. 199, 200.

** Ibid., pp. 213, 214.

Van Hise and Clements regard the greenstone schists of the Crystal Falls iron-bearing district as altered diabase, diabase-porphyry, and gabbro.* Clements † has shown the derivation of the greenstones of the Hemlock formation to be from original basaltic and andesitic rocks.

The evidence here adduced from the descriptions of the rocks of the several areas indicates the striking fact that the present altered rock, greenstone, is remarkably similar for the several districts, but when, through chemical and microscopic means, they are traced to the original rock, distinct differentiation, such as distinguishes the various basic igneous types from each other, is shown. Moreover, not only is this striking similarity indicated in the altered rock in each instance, but the processes involved in producing the alteration have been uniformly alike. The alteration has been one of structural and chemical metamorphism, resulting in the formation of abundant chlorite and epidote and smaller amounts of other secondary minerals and the accompanying secondary schistose structure.

ORE DEPOSITS OF THE DISTRICT ‡

The deposits of the immediate district are copper, with those of workable iron ore reported from other portions of the same counties. Copper prospecting in the district dates back forty or fifty years. The Gillis copper mine was opened in 1856,§ exposing a large body of copper glance. Systematic work is of recent date, however.

The ore occurs mostly in quartzose veins, and to a limited extent as finely divided particles disseminated through the rocks in places. The workable ore is confined entirely to the veins. The vein stone consists principally of quartz with considerable calcite and epidote mixed locally. The altered country rock, greenstone, is intimately mixed with the quartz and calcite as thin lenses and stringers, which impart, in places, a banded structure to the vein. The included portions of the altered rock vary from mere films and dark streaks in the quartz to a preponderance of the schist with quartz infiltrated between the layers. The quartz is further frequently encased by layers of the schist wrapped around it.

The workable ore comprises glance and bornite mixed with the green carbonate, malachite—an alteration product from the original sulphides. A considerable sprinkling of the red oxide and native copper are seen in places. Genth and Kerr[*] mention the following copper minerals occurring in Person and Granville counties: chalcopyrite, chalcocite, malachite, chrysocolla, cuprite, and native copper. Chalcopyrite and pyrite are almost entirely absent from these veins. They were observed in largest amount at several shafts being opened on the High Hill property in Virginia at the time of the writer's visit.

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* Mono. U. S. Geol. Survey, vol. xxxvi, pp. 484–486 ; ibid., vol. xxviii, pp. 203-208.

† Ibid., vol. xxxvi, pp. 95–148.

‡ For a detailed description of the individual mines and the general features of the belt as a whole, see W. H. Weed, Trans. Amer. Inst. Min. Engrs., 1901, vol. xxx, pp. 449–504. An earlier account is given by Geo. B. Hanna in Ores of North Carolina, 1888, pp. 214–220.

§ Emmons, E., Geol. Survey of North Carolina, 1856, p. 344.

So far as examined, the ores are free from arsenic and antimony, but are reported to carry, at times, very appreciable traces of both gold and silver, particularly the latter. The following assays of the gray ore from the Yancey mine in Person county, North Carolina, are given by Hanna,[†] and serve to illustrate the values of the mineral material.

Gold, per ton,	$\frac{1}{10}$ ounce,	$\frac{1}{10}$ ounce,	$\frac{1}{10}$ ounce.
Silver, per ton,	$6\frac{7}{10}$ ounces,	$5\frac{1}{10}$ ounces,	$\frac{1}{2}$ ounce.
Copper, per cent,	48.17	26.16	31.14.

In the Holloway shaft, 3.5 miles south of Virgilina, the vein has been opened to a depth of more than 500 feet, and the action of the percolating carbonated waters is shown to this depth in the occasional presence of the green carbonate, malachite, in association with the unaltered ores.

The particular interest in the ore deposits of this district is the somewhat analogous occurrence and association in many respects of the copper minerals, including native or metallic copper, in the greenstones (originally igneous in origin) to certain closely allied areas of altered igneous rocks of the Lake Superior region, and the Catoctin and South mountain areas of Virginia-Maryland-Pennsylvania, and to other smaller and less important areas in Virginia and North Carolina. Furthermore, the association of the copper with epidote is not only true of the Virgilina belt, but is described by various geologists[‡] as true to some degree for the other areas of the Atlantic Coast and Lake Superior regions. No indications of amygdaloidal structure so common in the rocks with which the copper is intimately associated in many of the other areas is found in the Virgilina district.

In describing the general distribution of the Catoctin type of copper deposits, Weed says:

> "It is evident that the association of epidote (and, to a lesser degree, of chlorite) and the native copper is a constant one, for which reason it is believed that the processes incident to the formation of the one led to the formation of the other. Such ores occur near Virgilina, Virginia, near Charlotte, North Carolina, and in many scattered localities through the South."[§]

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[*] The Minerals and Mineral Localities of North Carolina, Raleigh, 1885, 128 pages; also Bulletin no. 74, U. S. Geol. Survey, 1891, pp. 98, 109.

[†] Op. cit., p. 220.

[‡] Op. cit.

[§] Trans. Amer. Inst. Min. Engrs., 1891, vol. xxx, p. 503.

The Ducktown copper deposits in southeastern Tennessee have been shown by Weed ‡ to represent a different type from the Virgilina deposits. Both Kemp † and Weed ‡ agree that the Ducktown ores are replacement deposits of an original calcareous sedimentary. A further difference consists in the Tennessee deposits being composed chiefly of chalcopyrite and pyrrhotite, which minerals are essentially absent from the Virgilina district.

WEATHERING

The superficial weathered product consists of a scanty covering of light gray to brown soil. At comparatively shallow depths beneath the surface the rock manifests no tendency toward disaggregation, nor to crumble and change color when exposed at the surface, but on the contrary remains hard and fresh appearing.

The greatly altered nature of these rocks has already been emphasized. The resulting minerals from such change, epidote and chlorite, are present in large amounts in these rocks, replacing in whole or in part the original essential minerals from which the above two have been derived. Epidote is usually regarded as a dynamo-metamorphic mineral, while chlorite is usually given as a product of weathering. The origin of chlorite, however, is sometimes closely associated with dynamic agencies. It is not possible, therefore, to separate the products of the processes which have produced the degree of alteration manifested in the rocks of this area. Without stating more detail, vastly the majority of change in the rocks of this area is due to dynamic action.

A suite of specimens representing the fresh and decayed rock were collected at the Anaconda mine in Virginia, a short distance north of Virgilina, for illustrating the chemical changes incidental to weathering. Here the decayed product is several feet deep, the brown color of the decayed rock passing gradually into the moderately fresh and firm green rock underneath. In columns VI and VII of the table of analyses are given chemical analyses of the fresh rock and its corresponding decayed product. The decayed rock was of a pronounced yellowish brown color, readily crumbling under slight pressure of the hand. It effervesced very feebly in dilute acid, indicating hardly more than appreciable traces of carbonates. When further digested for some time in very dilute warm HCl, the brown coloring matter was removed and the residue consisted of the usual green mineral products composing the fresh rock. The percentage of residue composed of the green colored minerals was very large.

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* Ibid., pp. 449–504.

† Ibid., Richmond Meeting, February, 1901, pp. 18–20 (author's edition).

‡ Ibid., 1891, vol. xxx, pp. 480–494.

As indicated in the analyses of the fresh and decayed rock of the table, the change has been one of hydration—the assumption of water, accompanied by the peroxidation of the iron and the partial removal of the more soluble constituents, lime, magnesia, and alkalies.

AGE RELATIONS

Excepting the northernmost extension of the Jura-Trias to the south and southeast in the vicinity of Oxford, Granville county, North Carolina, no known clastics of definite age are found close to the area. Dikes of Mesozoic diabase are reported to be rather numerous in parts of Granville county, and in several instances are observed cutting the rocks of this area. To the east, south, and west massive granites and granitic gneisses of approximately the same mineral composition are of frequent occurrence. Sufficient work has not yet been done, however, to definitely determine the exact origin of the gneisses, but in many cases their close mineralogical resemblance to the granites is suggestive of igneous origin. Indeed, a chemical analysis quoted by Kerr [*] of a similar granitic gneiss taken from the Raleigh quarries would strongly indicate, in connection with the mineral components, an original massive granite sybsequently rendered schistose by pressure.

The occurrence of similar ancient volcanic rocks in the adjoining counties to the southeast of the Virgilina area, described by Williams [†] and others [‡] as closely resembling those of the South Mountain area, are grouped as pre-Cambrian in age, and can be most likely correlated with the rocks of the Virgilina district.

The rocks of this district are shown to be quite similar in many respects to the volcanics farther north in Virginia and Maryland of the Catoctin belt and of South mountain, a continuation of the Catoctin belt in Pennsylvania. Keith [§] has shown the rocks of the Catoctin belt to be pre-Cambrian—Algonkian—in age. Likewise Williams [||] and Bascom [¶] have shown the series of both acid and basic volcanics of South mountain in Pennsylvania to be of the same age—Algonkian.

The rocks the Virgilina district are, with few exceptions, shown to be highly schistose in structure, which is a secondary structure, and indicates that the area has been subject to long-continued dynamo-metamorphism. In view of these facts and in the absence of contradictory field evidence, the rocks are placed as pre-Cambrian in age. This is in accord with the work of Kerr and Holmes, who agree in assigning the rocks of this area to the Huronian (Algonkian),* and with that of Keith,† Williams,‡ and Bascom § for somewhat similar volcanics occurring to the north in Virginia, Maryland, and Pennsylvania.

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[*] Geology of North Carolina, Geol. Survey of N. C., 1875, vol. i, p. 122.

[†] Jour. of Geology, 1894, vol. ii, pp. 1–31.

[‡] Gold Deposits of North Carolina, Geol. Survey of N. C., Bulletin no. 3, 1896, pp. 37–43; ibid., Bulletin no. 10, 1897, pp. 15, 16.

[§] Geology of the Catoctin Belt, 14th Ann. Rept., U. S. Geol. Survey, 1894, p. 319. See map, plate xxii, opposite p. 308.

[||] Volcanic Rocks of South Mountain in Pennsylvania and Maryland, Am. Jour. Sci., 1892, vol. xliv, pp. 493, 494; Jour. of Geology, 1894, vol. ii, pp. 1–31.

[¶] The Ancient Volcanic Rocks of South Mountain, Pennsylvania, Bulletin no. 136, U. S. Geol. Survey, 1896, p. 30.

[¶] Jour. of Geology, 1893, vol. i, pp. 813–832.

It further harmonizes with the work of Williams ‖ and Nitze ¶ in the adjoining counties to the southwest of the Virgilina district, where similar rocks are described and classified as pre-Cambrian in age. Subsequent work will probably establish the contemporaneous origin of the rocks for the several scattered areas.

CONCLUSIONS

The principal points developed in this study may be summarized as follows:

1. The rocks of the area here described have been greatly altered through pressure and chemical metamorphism, as indicated in the prevailing secondary schistose structure and the abundant development of the secondary minerals—chlorite, epidote, and hornblende—and small amounts of others. The alteration has advanced sufficiently far in the schistose phases to destroy in most cases the original structure and minerals of the rock.

2. From structural, petrographic, and chemical evidences the rocks are shown to have been derived from an original andesite, but in their present much altered state they are, according to present usage, more properly designated meta-andesites; that these are intimately associated with the corresponding volcanic clastics. Furthermore, the popular name greenstone applied to many areas of greatly altered massive and schistose rocks along the Atlantic Coast and Lake Superior regions, shown to have been derived from an original basic eruptive rock type, has equal application to the existing rocks of the Virgilina district.

3. The rocks are pre-Cambrian in age and represent an area of ancient volcanics similar to others described as occurring along the Atlantic Coast region from eastern Canada to Georgia and Alabama and in the Lake Superior region.

4. The rocks are cut by numerous approximately parallel quartz veins which contain workable copper deposits. The veins have been described as true fissure veins, and the ore is glance and bornite, without chalcopyrite and pyrite.

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* Van Hise, C. R.: Correlation Papers, Bulletin no. 86, U. S. Geol. Survey.

† Op. cit. ‡ Op. cit. § Op. cit. ‖ Op. cit. ¶ Op. cit.

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CATALOG OF PHOTOGRAPHS BELONGING TO THE GEOLOGICAL SOCIETY OF AMERICA

BY N. H. DARTON

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INTRODUCTION

This catalog gives the titles of all the photographs which have been donated to the Society up to the end of May, 1902. It is arranged alphabetically by states and countries. The numbers are from 1 to 1418. There is also a subject index with headings of some of the principal geologic phenomena under which the numbers and brief titles of the photographs are given in numerical order.

The original number of photographs was 2,037, as given in catalogs of accessions published in the Proceedings from volumes 1 to 12. It was known for some time that the collection had become too bulky and contained a large amount of worthless material. On my suggestion a committee was appointed, consisting of G. K. Gilbert, J. S. Diller, and myself, with authority to exclude the undesirable views. This was done in 1901, photographs being rejected only when there was unanimous agreement. By this means the collection was reduced to its present size. It was rearranged by states and renumbered; photograph No. 1 representing Alabama, and photograph No. 1359 concluding those under Wyoming; then follow Nos. 1360 to 1418, including various miscellaneous views which could not be arranged geographically. Many minor changes were made in the arrangement of the prints so as to materially diminish their bulk.

The collection is now in excellent condition, stored in my office in the building of the U. S. Geological Survey, Washington, D. C., where it is safe from fire, and accessible to a larger number of geologists than it would be in any other locality. During my absence from the city in the summer months the keys to the two boxes containing all of the mounted photographs are deposited with the Chief Clerk of the Survey, who will give members access to the photographs.

The collection includes a very large amount of fine material, suitable for illustrating geological reports, etc., and for lantern slides. About two-thirds of the negatives are the property of the United States Geological Survey. These negatives have recently been numbered throughout. Their numbers are given in parentheses in this catalog, as well as having been placed on the photographs themselves, which will aid greatly in the ordering of prints or slides. All photographs ordered from Survey negatives should be designated by the name of the photographer and the Survey number and not by the Geological Society of America's number. Applications for prints and lantern slides should be made to the Director of the United States Geological Survey. Prints are obtainable at the following prices:

Size.	Unmounted.	Mounted.
11 by 14 inches	30 cents	35 cents
8 by 10 inches	20 cents	25 cents
6½ by 8½ inches	15 cents	20 cents
5 by 7 or 8 inches	12 cents	15 cents
4 by 5 inches	8 cents	10 cents

Lantern slides will be made at the uniform rate of 50 cents each. In orders of 100 and over, the slides will be made for 45 cents each.

The negatives given to the Society by the Second Geological Survey of Pennsylvania have been stored in the photograph gallery of the United States Geological Survey in Washington. and they may be ordered by Mr Harden's numbers as given in this catalog.

The Committee on Photographs desires to obtain additional material for the collection when it is of a character to clearly illustrate geologic phenomena, structural, stratigraphic, glacial, volcanic, or physiographic. General views of scenery which require explanation as to their geologic significance are not acceptable.

ALABAMA

Photographed by I. C. Russell

8 by 10 inches. Negative in United States Geological Survey

1. Falls of Black creek, near Gadsden, 100 feet high (No. 59).

ALASKA

Photographed by G. K. Gilbert

5 by 7 inches. Negatives in United States Geological Survey

2. Drowned foreland, Kadiak, Alaska (No. 399).
3. Cleavage in Yakutat shales, near Kadiak, Alaska; more nearly vertical in argillaceous (darker) strata than in arenaceous (paler) strata (No. 395).
4. Drift-strewn surface, laid bare within twenty years by the Hugh Miller glacier, Glacier bay, Alaska (No. 281).
5. Section of moraine ridge on Hidden glacier, Alaska, showing protection of ice from ablation by a veneer of drift (No. 370).
6. Freshly formed kettle hole in gravel derived from the Hidden glacier, Alaska (No. 371).
7. Gravel waste plain of the Hidden glacier, Alaska, showing incipient kettle hole (No. 372).
8. Push moraine of Crillon glacier, Alaska, showing disturbed forest (No. 333).
9. Push moraine, made probably in 1892 by the Columbia glacier, Alaska (No. 356).
10. Delta in Gastineau channel at Juneau, Alaska, as seen at low tide (Nos. 470 and 471).

Photographed by I. C. Russell, 1891

5 by 7 inches. Negatives in United States Geological Survey

11. Mount Saint Elias, from western end of Samovar hills (No. 551).
12. Southern face of mount Saint Elias (No. 539).
13. Ice cascade in Agassiz glacier, partially covered by new snow (no negative).
14. Cascade in the névé of Newton glacier (no negative).
15. Cascade in the névé of a tributary of Agassiz glacier (no negative).
16. Canyon on the Chaix hills (No. 400).
17. Marginal drainage, southern base of Chaix hills; looking westward (No. 541).
18. Mount Saint Elias, from Malaspina glacier south of Chaix hills (No. 544).
19. Abandoned lake beds, south side of Chaix hills (No. 555).
20. Yahtse river, from above ice tunnel; looking southward (No. 543).
21. Yahtse river, issuing from a tunnel in Malaspina glacier (No. 552).
22. Moraine-covered surface of Malaspina glacier, near point Manby (No. 548).
23. Surface of central portion of Malaspina glacier (No. 550).
24. View from southern margin of Malaspina glacier (No. 545).
25. Sitkagi bluffs; southern margin of Malaspina glacier (No. 558).
26. Surface of alluvial fan of the Yahtse; showing partially buried forest (No. 546).
27. Icebergs stranded at low tide; shore of Yakutat bay (no negative).
28. Tree broken by recent advance of Malaspina glacier (No. 554).
29. Vegetation about southern border of Malaspina glacier (No. 559).
30. Southern margin of Malaspina glacier; showing forest growing on the glacier (No. 540).
31. Second view of alluvial fan on esker stream (No. 542)
32. Glaciated surface on Haenke island (No. 549).
33. Vegetation on Malaspina glacier (no negative).

Photographed by H. F. Reid, Johns Hopkins University, Baltimore, Maryland, 1890

Negatives in Professor Reid's possession

Nos. 51 to 65, 6 x 8 inches; Nos. 34 to 50, size 3 x 4, Kodak views. Professor Reid's numbers are given in parentheses. (Some of these views are published in Professor Reid's paper, "Studies of the Muir Glacier," in the National Geographic Magazine, volume 4, 1892, pages 19-84, plates 1-16.)

34. Upper part of Dirt glacier (No. 132).
35. Western tributary of Muir glacier (No. 71).
36. Berg lake from lower down on Tree mountain (No. 120).
37. View of second northern tributary behind mountains on the right; Black mountains on the left (No. 68).
38. Girdled glacier and Granite canyon (No. 40).
39. Diorite peaks, from snow dome (No. 58).
40. Looking down main valley. Tree mountain in extreme right; mount Young on extreme left (No. 47).
41. Rock basin on top of Nunatak, Muir glacier (No. 8).
42. Origin of western subglacial stream; ridge at end of glacier (No. 103).
43. View from north, showing mouths of Girdled glacier and Granite canyon (No. 22).
44. Ice-front of Muir glacier from the west (No. 30).
45. Ice-front of Muir glacier.
46. Ice-front of Muir glacier, nearer view (No. 85).
47. Morainal ridge (No. 104).
48. Moraine coming out of main valley (No. 128).
49. Big rock on moraine (No. 131).
50. Another view of cone of round stones (No. 134).
51. Ice-front of Muir glacier and delta of western subglacial stream (No. 207).
52. Mounts Chase and Wright and Muir glacier (No. 200).
53. Ice-front of Muir glacier (No. 205).
54. Ice-front of Muir glacier, from Camp Muir (No. 206).
55. White glacier, mount Chase on right (No. 214).
56. Mount Wright, from shoulder of mount Chase (No. 203).
57. Mount Young (No. 216).
58. Buried forest, looking eastward, mount Chase in the distance (No. 221).
59. Buried forest, looking westward (No. 220).
60. Moraine near end of Muir glacier (No. 213).
61. Limestone mountain and stranded iceberg, about 10 miles south of Muir glacier bay (No. 217).
62. Part of ice-front of Muir glacier and stranded ice (No. 208).
63. Wing of Muir glacier overriding roughly stratified deposits (No. 209).
64. A stranded iceberg; a nearer view than 63 (No. 210).
65. Pinnacles at the end of Muir glacier (No. 211).
66. Glacier draining into tidal inlet (No. 258).
67. Mount Chase (No. 303).
68. Mount Young (No. 305).
69. Muir glacier, from Caroline shoals (No. 312).
70. Rounded limestone on Drake island (No. 333).
71. Geikie glacier, Hugh Miller inlet (No. 354).

72. Mountains between Tidal and Queen inlets; from across the bay, looking northeast (No. 362).
73. View in Hugh Miller inlet (No. 364).
74. First northern tributary of Muir glacier (No. 374).
75. Mount Wright (No. 380).
76. Muir glacier (No. 381).
77. Junction of Girdled with Muir glacier (No. 385).
78. Junction of Girdled with Muir glacier (No. 389).
79. Mount Fairweather; upper part of Glacier bay (No. 398).
80. Looking up Rendu inlet, from Halfbreed island (No. 407).
81. Carroll glacier (No. 410).
82. Glacial scratches at the north end of Sebree island (No. 413).
83. Muir glacier and mount Case; looking eastward (No. 414).
84. Stream terraces at end of Muir glacier (No. 418).
85. Ice-front of Muir glacier (No. 420).

Photographed by J. Stanley-Brown, 1318 Massachusetts Avenue, Washington, D. C.

6½ by 8½ inches. Negatives in possession of Mr. Stanley-Brown

86. Lava flows, Saint Paul island.
87. Sea-dissected cinder cone, Saint Paul island.
88. Crater lake, 300 feet above sea, Saint Paul island.

Photographed by F. C. Schrader, 1898-1899

5 by 7 inches. Negatives in United States Geological Survey

89. Down Gens de Larg river from sand dune; looking southeast (No. 7).
90. Till Bluff terrace; from north shore of Gens de Larg river, 75 miles above mouth of river; looking east (No. 24).
91. Juneau, from rear edge of town; looking southwest across Castinyas channel to Treadwell mines, on Douglas island (No. 243).
92. Faulted graywacke, shale, and sandstone in young rock series; looking west (No. 249).
93. Valley tributary to the Gens de Larg river, 112 miles above its mouth; looking west by south (No. 42).
94. Lower side of gulch and topography above Green mountain, in the middle of valley, about 180 miles above mouth of river; looking northeast (No. 107).
95. Dark limestone, with schistosity and quartz, 1,896 miles above mouth of Gens de Larg river; looking southwest (No. 113).
96. Gens de Larg rapids, 128 miles above mouth of river; looking northeast (No. 58).
97. Chugatch mountains. Sheep mountain (4,200 feet) and vicinity, on south side of Port Valdes, above Swanport, from Giant Rock island; looking east (No. 20).
98. Valdes and mountains on north, mount West in right, from east beach and foot of delta (No. 52).
99. Dyea, mouth of valley and mountains on east, from roadside bluff south of bridge (No. 2).
100. Range along north shore of Port Valdes, from Potato point (No. 18).
101. Foot of Valdes glacier, showing moraine-covered ice (No. 76).

102. Port Valdes. Pack train (Lowe's) ascending terminal moraine in front of Valdes glacier; looking up (No. 66).
103. Valdes glacier. Section of crevasse and ridge; ice topography, with mountains in east 2 miles distant, and elevated serac feeder in right, from Government trail on west edge of glacier; looking across the glacier (No. 72).
104. Looking south from Valdes over glacial delta to Chugatch mountain (Nos. 85 and 86).
105, 106. Summit of Valdes glacier, near Klutena glacier.
107. Klutena river at Devils elbow (No. 103).
108. Silt bluffs on east side of Klutena river, from terrace on west, 150 feet above river; looking across the valley and river (No. 100).
109. Mount Drum in center and Tillman in extreme right. Copper River district (No. 115).
110. Looking down the Copper river, showing mountains below Chettyna (No. 120).
111. Mount Blackburn, mouth and delta of Chettyna river (No. 137).
112. "Stick" natives—family, dogs, house, and fish racks (No. 139).
113. Dewey creek, and topography opposite Konsina on the east side of Copper river (No. 147).
114. Foothills and mountains on Copper river, above Tasnuna (No. 161).
115. Cleve valley from moraine near foot of glacier (No. 150).
116. Foot of Woods canyon on Copper river, looking up stream.
117. Plateau and mountains near head forks, Gens de Larg river; from Fork point, about 7 miles above camp 28, at mouth of Portage creek, or 204 miles above mouth of river; looking east-northeast (No. 122).
118. View up Portage creek and canyon, near mouth of Portage creek, 194 miles above mouth of river; looking south-southwest (No. 139).
119. Down Gens de Larg River valley, at mouth of Portage creek, 193 miles above mouth of river (Nos. 118–119).
120. Mountains of limestone and mica-schist, down north side of Robert creek; from Horace peak, 6,000 feet, on headwaters of Koyukuk river, 652 miles above its mouth; looking north-northwest (No. 174).
121. Mountains of limestone and mica-schist, down north side of Robert creek; from Horace peak, 6,000 feet, on headwaters of Koyukuk river, 652 miles above its mouth; looking southwest (No. 172).
122. Mountainous region, on headwaters of Koyukuk river.
123. On Tasnuna river. Front of Woodworth glacier. Shows topography of moraine-covered ice-front (No. 181).
124. Woodworth glacier near foot, where cut by Tasnuna river (No. 185).
125. Tasnuna river at foot of First glacier (No. 179).
126. On Tasnuna river. Quartz gash veining in blue quartz schist bedrock, ½ mile above canyon; looking north (No. 195).
127. Beginning of clay and gravel bluffs in Middle fork, Koyukuk river, above mouth of Baker creek, 606 miles above mouth of Koyukuk river; looking northwest (No. 220).
128. Limestone ridge and gully; weathering. On north side of Bettles river, 628 miles above the mouth of Koyukuk river (No. 196).
129, 130. Mountains of limestone and mica-schist on east side of Diedrick river, on Fault mountain, 5,400 feet; looking east. Faulting of limestone in right (No. 213, panorama).

131. Canyons in young rock series, 1 mile below Tramway bar; looking northwest (No. 242).
132. Sluicing the gold placers by Elsingson party on claim 11, Myrtle creek; looking north-northeast (No. 229).
133. Gold-bearing schist, showing cleavage and attitudes of rock in bed of Myrtle creek; looking northeast (No. 224).
134. Young rock series of sandstone and conglomerate with some lignite, 8 miles above camp 38; looking west-northwest (No. 238).
135. Elephant mountain; from 3 miles above mouth of Koyukuk river; looking southwest (No. 377).
136. View down Koyukuk river, showing low plateau topography, ripple-marks, and native village in distance; 135 miles above mouth of river (No. 353).
137. View down Yukon river, showing Nulato plateau, from ½ mile above edge of flats, on right bank of Yukon, between Koyukuk station and Pickart's coal mine; looking southwest (No. 390).
138. Up Koyukuk river, showing flats with rock plateau and mountains in rear; 26 miles above mouth of river; looking west-northwest (No. 370).
139. Bergman and edge of young rock series plateau; opposite Bergman; looking north-northwest across Koyukuk river (No. 280).
140. Mountainous topography of Nome River valley (No. 433).
141. Snake River valley in vicinity of Nome, showing merging of tundra into alluvium (No. 438).
142. Part of Nome tundra, Nome Sledge island and Bering sea in distance (No. 424).
143. Edge of tundra and beach of Nome (No. 442).
144. Nome beach diggings (No. 440).
145. Nome beach gravels, auriferous ruby sand at base (No. 443).
146, 147. View across Glacier creek, valley of upper Snake river near Nome.
148. Anvil Creek valley near Nome. Bering sea and tundra in distance.
149. Anvil Creek diggings, Nome.

Arizona and New Mexico

Photographed by W. H. Jackson, Detroit, Michigan

Lantern slides, 50 cents each

150. Grand canyon of the Colorado. Size, 21 by 74 inches; mounted, $17.50; not mounted, $15.00.

Photographed by J. K. Hillers

11 by 14 inches. Negatives in United States Geological Survey

151. Grand canyon of the Colorado at the foot of the Toroweap, in Arizona. The outer canyon, of which only the northern wall is seen, is here 5 miles wide and 2,000 feet deep. The inner gorge, cut in the floor of the outer one, is 3,000 feet deep and from 3,500 to 4,000 feet wide from crest to crest. Published in Tertiary History of the Grand Canyon District, by Captain C. E. Dutton, page 86 (No. 80).
152. Shinimo altar from the brink of Marble canyon of the Colorado river, Arizona (No. 81).
153. Canyon de Chelly, Arizona (No. 118).

154. Walnut canyon, Arizona. Bedding and cross-bedding. Ruins of cliff dwellings on the left (No. 130).
155. Navajo church near Fort Wingate, New Mexico. Prominent columns of erosion, cross-bedding (No. 122).

Photographed by Cosmos Mindeleff

8 by 10 inches

156. Fault in calcareous clays and sands, eastern side of Rio Verde, 8 miles below Camp Verde, Arizona (negative not available).

CALIFORNIA

Photographed by J. K. Hillers

11 by 14 inches. Negatives in United States Geological Survey

157. Big trees, Mariposa (No. 50).
158. Yosemite Falls cliff (No. 38).
159. The Sentinel, Yosemite valley (no negative).
160. El Capitan, looking southeast (No. 44).
161. El Capitan, looking west, Yosemite valley (No. 41).
162. Washington column, Yosemite valley (No. 46).
163. Home of the Storm Gods, Yosemite valley (no negative).
164. Three Graces, Yosemite valley (No. 37).
165. Royal Arches, Yosemite valley (No. 36).
166. Royal Arches (No. 35).
167. Home of the Storm Gods, Yosemite valley (No. 43).
168. Yosemite valley, general view (No. 40).
169. El Capitan from the trail, Yosemite valley (No. 49).
170. Cathedral Spires, Yosemite valley (No. 34).
171. Shingle, Yosemite valley (No. 42).
172. Yosemite Falls cliff (No. 48).
173. Three Brothers, Yosemite valley (No. 39).

Photographed by W. H. Jackson, Detroit, Michigan

21 by 16 inches. Price, $2.50, mounted; $2.00, unmounted; lantern slide, 50 cents

174. South dome; from Glacier point, Yosemite valley (No. 1344).

Photographed by C. D. Walcott

5 by 7 inches. Negatives in United States Geological Survey

175. Granite point near trail and glacial lake on Conness Peak trail, Yosemite National park (No. 349).
176. Granite showing effect of cleavage fractures in producing forms of erosion, Conness Peak trail, Yosemite National park (No. 350).
177. The dome above Nevada falls, Yosemite National park (No. 363).
178. Domes above Nevada falls, Yosemite National park (No. 364*b*).
179. Liberty cap, above Nevada falls, Yosemite National park (No. 365*c*).
180. Fractures in granite at base of Liberty cap, Yosemite National park (No. 366).
181. Vernal falls, Yosemite National park (No. 368).
182. Cliffs above Mirror lake, Yosemite National park (No. 374*b*).
183. The arches, Yosemite valley (No. 376).

Photographed by H. W. Turner

6½ by 8½ inches. Negatives in United States Geological Survey

184. Crescent lake, in the Yosemite National park. The morainal dam which has formed the lake is shown, the outlet being in the middle, where the driftwood has accumulated (No. 110).
185. View from near Sentinel dome, in the Yosemite National park, showing the canyon of Tenaya creek and the roches-moutonnées-like surface of the plateau north of Yosemite valley (no negative).
186. Rock basin in biotite-granite. Ridge south of Morrison creek, in the Yosemite National park. The diameter of the basin is about 1 meter and its depth about 15 centimeters. They are formed by atmospheric agency without aid of running water (no negative).
187. Showing the weathering of biotite-granite on ridge south of Morrison creek, a branch of the Tuolumne river, in the Yosemite National park. On the boulder to the left may be seen several little rock basins which by growth have coalesced (no negative).
188. Exfoliating granite east of Royal Arch lake, which drains into the South Merced river, in the Yosemite National park (No. 112).
189. Exfoliating granite on slope northwest of Grouse lake, in the Yosemite National park. The different steps formed by the layers are all glaciated, showing that the exfoliation took place before the final retreat of the ice (No. 111).
190. Exfoliating granite on slope northwest of Grouse lake, in the Yosemite National park. The large boulders in the foreground are polished on their upper surface and have been fractured and moved by frost and heat into their present position since the retreat of the ice (No. 109).
191. Boulder of an igneous pudding-stone on north ridge of Yosemite valley. It is composed of nodules of diorite cemented by biotite-granite. The measure is 25 centimeters long (no negative).
192. Granite striated and polished by the ice, near Johnson lake, in the Yosemite National park (No. 113).

Photographed by J. K. Hillers

11 by 14 inches. Negatives in United States Geological Survey

193. Kings river, California (No. 57).
194. The Jungle, Kings river, California (No. 58).
195. Moores cliff, Kings river, California (no negative).
196. Cabin point, Kings river, California (No. 55).
197. Junction cliff, Kings river, California (no negative).
198. Sentinel cliff, Kings river, California (No. 56).

Photographed by or for J. S. Diller, 1884

8 by 10 inches. Negatives in United States Geological Survey

199. Mount Shasta from the western base, near the railroad station at Sissons (No. 24).
200. Mount Shasta from the north, after the first snowfall of September, 1884.

201. Near view of mount Shasta from the north. Mount Shasta on the left is 2,000 feet higher than Shastina on the right. The gray pile at the foot of the snow between them is the terminal moraine of the Whitney glacier. To the left of this is the terminal moraine of the Bulam glacier (No. 40).
202. Whitney glacier, crevasses and moraine, northwestern slope of mount Shasta (No. 36).
203. Bulam glacier and moraine, northern slope of mount Shasta (No. 32).
204. Mount Shasta from the east (No. 56).
205. Hotlum glacier and moraine, eastern slope of mount Shasta (No. 64).
206. Glaciated rocks, southeastern slope of mount Shasta (No. 77).
207. Moraine of late glacial field at western base of Lassen peak, California (No. 216).
208. Glacial striæ, north Yallo Bally mount, Coast range, California (No. 38*a*).

Photographed by J. S. Diller

8 by 10 inches. Negatives in United States Geological Survey

Nos. 209 to 215 are published in the Bulletin of the Geological Society of America, volume 1.

209. Sandstone dike penetrating Cretaceous shales, Dry creek, Tehama county, California. The dike is 18 inches thick and has well developed parallel and transverse joints (No. 100).
210. Great sandstone dike on Roaring river above Drews. The dike is 5 feet thick and can be traced about 9 miles (No. 101).
211. Lateral view of a wall-like sandstone dike on Crow creek, Shasta county, California. The transverse joints in the dike are parallel to plane of bedding in the shales seen at the right. The exposure is 20 feet high (No. 103).
212. Sandstone dikes cutting Cretaceous shales on Roaring river, Shasta county, California. The larger dike is 12 inches and the other 6 inches thick (No. 104).
213. Group of sandstone dikes on north fork of Cottonwood creek 1 mile above Gas point, Shasta county, California. The largest dike is 4 inches thick (No. 105).
214. Sandstone dike occupying a joint in Cretaceous shales, 1 mile above Gas point, on the north fork of Cottonwood creek, Shasta county, California. The dike is 4 inches thick (No. 106).
215. Lateral view of sandstone dike, Dry creek, Tehama county, California (No. 107).
216. Sandstone dike penetrating Cretaceous sandstones and shales, Dry creek, Tehama county, California. The dike is 10 inches thick below (No. 108).

Photographed by I. C. Russell

8 by 10 inches. Negatives in United States Geological Survey

Mostly published in the Eighth Annual Report of the United States Geological Survey.

217. Towers of calcareous tufa formed by sublacustral springs, shore of Mono lake, California (No. 67).

218. Perched boulder, near Jura lake, Mono valley, California (No. 36).
219. Joints in granite, mount Lyell, California (No. 56).
220. Gibbs canyon, from Williams butte, Mono valley (No. 32).
221. Bloody canyon, south of Mono lake (No. 79).
222. Lake canyon, near Mono lake. Partially refilled after being glaciated (No. 70).
223. Mount Lyell, from the Tuolumne meadows, California (No. 52).
224. End of Obsidian flow, Mono craters, Mono valley, California (No. 62).
225. Mono crater, from the south (No. 61).
226. Eolian erosion in rhyolite, Mono valley (No. 92).
227. Tuolumne valley, California, showing upper limit of ancient glacier (No. 87).
228. Mount Dana, California, from the west. A small glacier on northern slope, glaciated country to the right (No. 74).
229. Mount Dana glacier, northern side of Mount Dana (No. 45).
230. Mount Dana glacier, northern side of Mount Dana (No. 46).
231. Mount Dana glacier, northern side of Mount Dana (No. 49).
232, 233. Double plate. Mount Lyell glacier, northern side of Mount Lyell, California (Nos. 53 and 51).
234. Glaciated dome in Tuolumne valley, California.
235. Contorted lake-beds near southern margin of Mono lake, California (No. 41).

Photographed by J. S. Diller

8 by 10 inches. Negatives in United States Geological Survey.

236. Burney falls, Shasta county, California. The upper portion of the falls is over basalt and the lower portion over infusorial earth (No. 235*a*).
237. Deposit of infusorial earth 110 feet thick near Great bend of Pitt river, Shasta county, California.
238. Hydraulic mining, Cherokee Flat, Butte county, California (No. 159*a*).
239. Lava-capped river bed of the ancient Sacramento, near Delta, California. The embankment midway between the river below and its ancient bed beneath the lava above is occupied by a railroad. The lava stream is from Mount Shasta and it follows the canyon of the Sacramento for nearly 50 miles (No. 97).

Volcanic Eruption in northern California

Photographed by J. S. Diller

8 by 10 inches. Negatives in United States Geological Survey

Nos. 240–251 are published in Bulletin 79, U. S. Geological Survey.

240. Model of cinder cone, lava field, and ash-covered slopes. The cinder cone is 640 feet high, the crater is 240 feet deep, and the lava field is about 3 miles long. Snag lake, at the left end of the lava field, was formed by the lava dam (No. 241).
241. Lava field and cinder cone, looking southwest across Lake Bidwell; Lassen peak in the distance (No. 280).

242. The cinder cone from the south, earlier lava partly covered by volcanic sand. The dead trees extend down 7 feet through the volcanic sand to the original soil beneath (No. 245).

243. The cinder from the east. Earlier lava near the cone is covered by volcanic sand; later lava in the foreground uncovered (No. 247*a*).

244. The lava field looking southeast from the base of the cinder cone toward Snag lake (No. 273).

245. Volcanic bombs at the base of cinder cone; the largest is 8 feet in diameter (No. 248).

246. Surface of lava field; breaking of the lava crust (No. 272).

247. The tree projecting from beneath the lava was pushed over by the advancing lava. The dead tree on the left extends 10 feet down through the coating of volcanic sand to the original soil beneath. The living trees, some of which are about 200 years old, have grown up entirely since the eruption (No. 275).

248. Lava dam which formed Snag lake at the time of the eruption and drowned the trees whose stumps are seen in the lake (No. 267).

249. Snag lake, with lava dam in the distance and the stumps of drowned trees in the foreground (No. 266).

250. Lava front at the corner of Snag lake (No. 268).

251. Near view of lava blocks on edge of lava field. The lava is basalt, which is remarkable in containing numerous phenocrysts of quartz, uniformly distributed throughout the mass. The white spots seen in the lava are quartz (No. 271).

252. Hand specimen of quartz basalt from lava field near Snag lake. The white spots are quartz (No. 269).

Photographed by C. D. Walcott

6½ by 8½, excepting Nos. 270, 272–274, which are 5 by 7 inches. Negatives in the United States Geological Survey

253. Overturned fold in Cambrian quartzites, north side of Silver canyon, White Mountain range, Inyo county, California (No. 213).

254. Cambrian quartzites showing vertical cleavage of the strata. Soldiers canyon, Deep Spring valley, Inyo county, California; White Mountain range (No. 215*b*).

255. Lower Cambrian quartzites showing vertical cleavage in massive layers and interbedded thin layers without cleavage. Soldiers canyon, above Deep Spring valley, White Mountain range, Inyo county, California (No. 217).

256. Lower Cambrian quartzites showing vertical cleavage in massive layers and interbedded thin layers without cleavage. Soldiers canyon, above Deep Spring valley, White Mountain range, Inyo county, California (No. 217*d*).

257. Nearer view of quartzite cliff on south side of Soldiers canyon, above Deep Spring valley, White Mountain range, Inyo county, California (No. 216).

258. View of low hills 1 mile southwest of Antelope springs, Deep Spring valley, Inyo county, California; showing synclinal in Cambrian limestones resting on quartzites (No. 224*e*).

259. View of granitic mountain range on side of Deep Spring valley, Inyo county, California (No. 226*d*).

260. Overlooking granite area on east slope of White Mountain range, from near divide on road leading from Deep Spring valley, California, to Fish Lake valley, Nevada (No. 228*c*).
261. View of Deep Spring valley, Inyo county, California; showing folded Cambrian strata on northwestern side of valley, as seen from the west (No. 225*a*).
262. The Sierra Nevada from Alvord station, 2 miles east of Big Pine, Inyo county, California (No. 202*b*).
263. Outline of crest of Sierra Nevada west of Big Pine, Inyo county, California; from Tollgate canyon, White Mountain range (No. 201*b*).
264. Panoramic view of a section of the White Mountain range north of road passing from Big Pine, Inyo county, California, to Deep Spring valley (No. 227*b*).
265. Different view, but same label as 266 (No. 208*d*).
266. Panoramic view of White Mountain range, Inyo county, California; from foothills of Sierra Nevada, looking across Owens valley (No. 207*a*).
267. White Mountain range directly east of Alvord station and north of Tollgate canyon, Inyo county, California (No. 207*b*).
268. Granite boulders resulting from the disintegration of massive granite, eastern slope of Sierra Nevada, 3 miles west of Big Pine, Inyo county, California (No. 205*b*).
269. Granite boulders resulting from the disintegration of massive granite, eastern slope of Sierra Nevada, 3 miles west of Big Pine, Inyo county, California (No. 205*a*).
270. Hill on north side of Deep Spring valley, Inyo county, California; showing strongly marked cleavage in granite (No. 220*a*).
271. Plicated layers of thin bedded chert in limestone etched by erosion. Lower (?) Cambrian (?) Hill 2 miles west of Big Pine, Inyo county, California (No. 206*b*).
272. View of end of ridge, illustrating faulting and thrust beds of Cambrian limestone and quartzitic sandstone, Waucobi canyon, Inyo range, California, about 3 miles above mouth of canyon (No. 496).
273. Nearer view of a portion of the strata shown by No. 272 (No. 497).
274. Western side of thrust plane seen in south wall of Devils gate, Inyo range, California (No. 498*a*).
275. View near headwaters of north fork of Big Pine creek, Sierra Nevada mountains, Inyo county, California (No. 501*c*).
276. Granite peak, rising from the south side of the divide, head of north fork of Big Pine creek, Sierra Nevada mountains, Inyo county, California (No. 504).
277. Broken granite peak rising from the north side of divide on north fork of Big Pine creek, Sierra Nevada mountains, Inyo county, California (No. 505).
278. View of upper lake on north fork of Big Pine creek, Sierra Nevada mountains, Inyo county, California (No. 507).
279. Folded limestone and intruded quartzitic sandstones, south side of Devils gate, Waucobi canyon, Inyo range, California (No. 511).

Photographed by H. W. Turner

5 by 8 inches. Negatives in United States Geological Survey

280. Laminated and roughly columnar fine grained pyroxene-andesite. Franklin Hill (Bidwell Bar atlas sheet), California. See Journal of Geology, volume iii, page 410 (No. 12).
281. Potholes in the granite of the canyon of the north fork of the Mokelumne river, California. See American Journal of Science, volume xliv, page 453 (No. 31).
282. Farewell gap, at the head of the drainage of a branch of the middle fork of the Kaweah river, Tulare county, California. In the southern Sierra Nevada. Elevation of the gap, about 10,500 feet (No. 20).
283. The shattered granite crest of the Sierra Nevada, about 6 miles southeast of Tower peak, in Tuolumne county, California (No. 47).
284. Glaciated canyon north of lake Eleanor, Tuolumne county, California, showing the roches moutonnée. All the rock is granite (no negative).
285. Granite bank west of Granite lake, Tuolumne county, California, showing basic nodules in the granite and dikes of aplitic granite (granulite of Levy) cutting both the main granite mass and the included nodules. See 14th Annual Report U. S. Geological Survey, page 480 (No. 46).
286. Basic (black hornblende and some feldspar) inclusions in porphyrite (altered andesite) dike by the middle fork of the Feather river. Sierraville atlas sheet (no negative).
287. Basaltic dikes in andesitic breccia on ridge south of Poker flat, Sierra county, California. Downieville atlas sheet (no negative).
288. Old andesite (porphyritic) tuffs west of the Salmon lakes, Sierra county, California; showing joint structure. The tuffs are of Jura-Trias age (No. 3).
289. Exfoliating granite; view on the crest of the Sierra Nevada about 3 miles south of Raymond peak, Markleeville atlas sheet. See 14th Annual Report U. S. Geological Survey, page 481 (No. 23).
290. Wind ripples in the sand near west entrance to Golden Gate park, San Francisco (no negative).
291. Wind ripples in the sand near north entrance to Golden Gate park, San Francisco (no negative).
292. Cascades hydraulic gold gravel mine, showing the deposits of a Tertiary river, east slope of the Grizzly mountains, Plumas county, California, Downieville atlas sheet (No. 10).
293. Fault scarp and depressed block to the east of it, at the head of Dogwood creek, Plumas county, California, Bidwell Bar atlas sheet (No. 13).
294. Neocene shore gravels resting unconformably in a water-worn surface of the Ione sandstones, 3 miles southeasterly from Buena Vista, Amador county, California, Jackson atlas sheet (No. 16).
295. Wind ripples in sand by north entrance to Golden Gate park, San Francisco (no negative).
296. Ione formation capped by Pleistocene gravels; south bank of Mokelumne river, just east of the Comanche bridge, Calaveras county, California, Jackson atlas sheet (No. 17).

297. Porphyritic granite near Granite lakes, Toulumne county, California. The larger potash feldspars are 2 inches long (no negative).
298. Glaciated granite about 6 miles north of Hetch-hetchy valley, looking north, Tuolumne county, California (No. 37).
299. Granite lake, Tuolumne county, California; showing the glaciated surfaces (No. 45).
300. Glaciated knob of columnar hornblende andesite, 3 miles west of Silver peak, Alpine county, California, Markleeville atlas sheet (No. 27).
301. Vertical fissures in granite, north of Charity valley, Alpine county, California, Markleeville atlas sheet (No. 26).
302. Moraines north of Pleasant valley, Alpine county, California. The valley lies immediately south 600 feet lower than the moraines seen in the middle of the picture, Markleeville atlas sheet (no negative).
303. West peak of mount Raymond, Alpine county, California, from Indian valley. The peak is composed of hornblende pyroxene andesite breccia, Markleeville atlas sheet (No. 25).
304. The summit of the Sierra Nevada, near Tower peak, Tuolumne county, California (No. 33).
305. The crest of the Sierra Nevada, Tower peak (No. 34).
306. Summit of the Sierra Nevada near Tower peak, Tuolumne county, California. View taken in July (No. 32).
307. From Charity valley, Alpine county, California; showing the fissures and glaciated granite, with lavas on the ridge tops; Hawkins peak (hornblende-andesite) in the distance, Markleeville atlas sheet (no negative).

CANADA

Photographed by Dr George M. Dawson

6½ by 8½ inches. Negatives in Geological Survey of Canada

308. Fraser river at Fountain, British Columbia (No. 57, September 16, 1889).
309. Part of the interior plateau of British Columbia, looking southeastward from Porcupine ridge (No. 79, August 27, 1890).
310. Glaciated surface of basalt (No. 77, August 26, 1890).
311. Gorge of Elk river, B. C. (No. 31, 1883).
312. Glacier and snow-field at head of Red Deer river, Alberta (No. 50, September 23, 1884).
313. Folded cretaceous rocks, headwaters of Cascade river, Alberta (No. 41, September 20, 1884).
314. Bluffs on Pelly river, Lethbridge, Alberta (No. 17, June 27, 1883).

Photographed by J. B. Tyrrell

6½ by 8½ inches. Negatives in Geological Survey of Canada

315. View northward along one of the upper Agassiz beaches, Manitoba (No. 10 1887).
316. Swampy island, lake Winnipeg, Manitoba (No. 6, 1889).
317. Swampy island, lake Winnipeg, Manitoba (No. 9, 1889).

318. Upper limestone of the Devonian, Swan lake, Manitoba (No. 88, 1889).
319. Dakota sandstone, near an old lake Agassiz shore line, Kettle hill, Swan lake, Manitoba (No. 96, 1889).
320. Ice-pressed boulder pavement, southern shore of Red Deer lake, Saskatchewan (No. 103, 1889).
321. Cliff of Niagara dolomite, Cedar lake, Saskatchewan (No. 30, 1890).
322. Trenton limestone, northwest shore of lake Winnipeg (No. 50, 1890).
323. Laurentian gneiss, southern shore of Little Play Green lake, in front of Norway house.
324. View of cliff on northern side of Deer lake, lake Winnipeg, Manitoba (No. 2, 1890.)

Photographed by T. C. Weston

6½ by 8½ inches. Negatives in Geological Survey of Canada

325. Magdalen river and bay, lower Saint Lawrence (No. 13, 1879).
326. Lower Helderberg rocks, Arisaig, Nova Scotia (No. 9, 1873).
327. Lower Helderberg rocks, Arisaig, Nova Scotia (No. 8, 1873).
328. Carboniferous rocks, southern shore, Joggins, Nova Scotia (No. 21, 1879).
329. Lower Cambrian rocks, "The Ovens", Lunenburg county, Nova Scotia (No. 14, 1879).
330. South Saskatchewan river; Northwest Territory (No. 8, 1889).
331. Pre-Cambrian contorted schists, Shipton, Maine (No. 11, 1873).

Photographed by R. W. Ells

11 by 14 inches. Negatives in Geological Survey of Canada

332. Twisted gneiss, southern shore of Ottawa river, opposite Montebello.
333. Twisted gneiss, southern shore of Ottawa river, opposite Montebello.
334. Twisted gneiss, southern shore of Ottawa river, opposite Montebello.
335. Twisted gneiss, northern shore of Ottawa river, opposite Papineauville.
336. Twisted gneiss, northern shore of Ottawa river, opposite Papineauville.

Photographed by H. G. Bryant, Philadelphia, Pennsylvania

Views of the Grand river and falls of Labrador. 4½ by 3¾ inches

337. Rapids above the falls.
338. Brink of the falls.
339. The Grand falls of Labrador.
340. Looking up stream above the falls.
341. Canyon below the falls.

Photographed by C. D. Walcott

6½ by 8½ inches. Negatives in United States Geological Survey

342. Conception bay, Newfoundland (No. 58).
343. Falls on Manuel's brook, Conception bay, Newfoundland (No. 57).
344. Anticlinal in Lévis terrace, on roadside leading up the bluff above Lévis railway station, province of Quebec, Canada (No. 14).

345. Southern shore of Saint Lawrence river, 9 miles below Quebec, Canada. Plication of shales and sandstones of Sillery terrace (No. 16).
346. Cherty layers interbedded in Sillery shales, 8 miles below Quebec, Canada, on the southern side of Saint Lawrence river (No. 18).
347. Unconformable contact of gneiss and Trenton limestone, ½ mile from Montmorency falls, Canada (No. 13).
348. Fault between Archean gneiss and Trenton limestone and Utica shale, just south of Montmorency falls, Canada (No. 11).
349. Conglomerate of limestone, quartz, trap, etcetera, boulders, situated about 1,500 feet down in Sillery red shales, 5 miles below Quebec, Canada, on south shore of Saint Lawrence river. Dr R. W. Ells, of the Geological Survey of Canada, in view (No. 21).

Photographed by S. R. Stoddard, Glens Falls, New York

5 by 8 inches. Price 30 cents each

350. Imbricating beach pebbles, at low tide in the bay of Fundy, 20 miles east of Saint Johns, N. B. (No. 1378).
351. Entrance to harbor of Saint John, N. B. (No. 1375).
352. Locality same as 351, "falls" at flood tide (No. 1374).
353. Low tide in the basin of Minas, Nova Scotia (No. 1398).
354. Low tide in the basin of Minas, Nova Scotia (No. 1399).

CENTRAL AMERICA

Photographed by R. T. Hill

5 by 7 inches. Negatives in United States Geological Survey

355. Costa Rica. Ira Zu volcano; ascent; outer view of crater (No. 37).
356. Costa Rica. Ira Zu volcano; outer view of crater, composed of rolling cinder (No. 38).
357. Costa Rica. Ira Zu volcano; detail of slope of ancient floor of large crater within crater, showing one stratum of black lava in great mass of cinder accumulation (No. 46).
358. Hicaron island, in Pacific ocean, showing topographic features and modern erosion described by Mr Hill in paper on Panama.

4 by 5 inches

359. Costa Rica. Crater lake of Poas volcano (No. 32).
360. Costa Rica. Crater lake of Poas volcano; geyser in operation (No. 33).
361. Costa Rica. Outer rim of Ira Zu volcano; altitude, 11,400 feet (No. 34).
362. Volcanic boulder drift, the chief geologic feature of Central America (No. 25).

COLORADO

Photographed by C. Whitman Cross

8 by 10 inches. Negatives in United States Geological Survey

363. View on Brush creek, Gunnison county, Colorado, to show the swath cut by a snowslide through a dense growth of spruce (No. 21).

364. Calcareous tufa bank, Cement creek, Gunnison county, Colorado. Face seen is 40 to 50 feet high, overhanging in places, forming grottoes (No. 11).

365. Calcareous tufa deposit, near view of central portion of bank shown in No. 364 (No. 12).

366. Eastern part of San Miguel mountains, Colorado. The sharp peak of mount Wilson (14,000 feet) is of diorite cutting up through Cretaceous and Eocene strata (No. 197).

367. Mount Wilson group, San Miguel mountains, Colorado. The smooth slopes of middle ground are of Cretaceous shales. The canyon in foreground is cut below the Dakota sandstone (No. 198).

368. Western portion of San Miguel mountains, Colorado. The sharper points are denuded laccoliths in Cretaceous shales. The plateau seen extends westward into Utah (No. 199).

369. Mountains north of the San Miguel river, near Telluride, Colorado. The lighter colored band of strata belong to an Eocene (?) conglomerate. Above it 2,500 feet of andesitic tuff and bedded breccia. Forms panorama with No. 370 (No. 205).

370. Mountains north of the San Miguel river, near Telluride, Colorado. Dallas peak (13,700 feet). Forms panorama with No. 369 (No. 206).

371. Mount Sneffels, San Juan mountains, Colorado (14,000 feet). A great diorite and gabbro mass cutting up through andesitic tuffs and breccias. Tertiary (No. 210).

372. A characteristic cliff of fine grained andesitic tuff. Bridal Veil basin, near Telluride, Colorado (No. 217).

373. South Lookout peak, near Ophir, San Juan mountains, Colorado. Characteristic cliffs and pinnacles of coarse bedded andesitic breccia and tuff (No. 222).

374. Iron spring near Ophir, Colorado. The spring has built up a terrace of reddish, sinter-like materials, as about the Yellowstone hot springs (No. 225).

375. The Twin Sisters peaks, San Juan mountains, Colorado. Jurassic strata form smooth slopes of middle ground; an Eocene (?) conglomerate, the cliff next above; Tertiary tuffs the peaks proper. Forms panorama with No. 376 (No. 231).

376. East of Twin Sisters peaks (forming panorama with No. 375). Triassic conglomerate causes cliffs of foreground. Eocene (?) conglomerate lies unconformably on Cretaceous, Jurassic, and Triassic strata on farther side of central valley (No. 232).

377. Vermilion peak, San Juan mountains, Colorado (13,700 feet). Typical cliffs of bedded breccias and tuffs. Rhyolite flows cause summit cliffs (No. 236).

378. La Plata mountains, Colorado; looking up Boren gulch from the southeast; Babcock and Spiller peaks in the center; the peaks mainly made up of a diorite stock cutting Mesozoic strata. An irregular diorite-porphyry body causes jagged cliffs on the left side of Boren gulch (No. 262).

379. Cliffs at the head of Bedrock gulch, La Plata mountains, Colorado; formation of cliffs is La Plata Jurassic sandstone, much indurated (No. 268).

380. A ravine at the head of Bedrock gulch, La Plata mountains, Colorado. The rock here is much shattered and highly altered diorite-porphyry (No. 270).

381. Mount Lewis, La Plata mountains, Colorado. View from the southeast. The peak consists of Triassic sandstones, etcetera, with numerous sheets and dikes of diorite-porphyry, and a small stock of diorite, producing much metamorphism of the strata (No. 272).

382. Silver peak, La Plata mountains, Colorado. View from the northeast. The mountain is a huge irregular mass of diorite-porphyry and diorite in Mesozoic beds (No. 274).

383. The Sharkstooth, La Plata mountains, Colorado. The upper exposures are of a diorite-porphyry sheet intruded into Cretaceous shales. The lower cliffs are of a sheet in the Jurassic shales; illustrates formation of talus slopes (No. 278).

384. Mount Wilkinson (or Table mountain), Gunnison county, Colorado. A remnant of a complex basalt sheet, resting upon Cretaceous sandstones. "Mesa" type of mountain" (No. 10).

385. Characteristic timber-line growth of stunted spruces, at an elevation of 12,100 feet, head of Cement creek, Gunnison county, Colorado (No. 29).

386. Meridian lake, near Crested Butte, Gunnison county, Colorado. One mile long, 200 to 500 feet wide. Occupies the crest of a ridge of soft Cretaceous shales. Crested Butte mountain in background (No. 50).

387. Mount Wheatstone, Gunnison county, Colorado (12,543 feet). Upper two-thirds of mountain a single mass of coarse porphyry, a laccolite from which all overarching strata have been eroded away; glacial amphitheaters in upper part (No. 17).

388. Teocalli mountain, West Brush creek, Gunnison county, Colorado (13,220 feet). Structure caused by beds of Carboniferous rocks, much metamorphosed by a large diorite mass behind the mountain (No. 18).

389. Typical scenery in the Elk mountains, Gunnison county, Colorado. Pearl mountain in the center, 13,484 feet; Brush Creek valley; timber line at 12,000 feet (No. 22).

390. Castle rock, near Golden, Colorado. A point projecting from the basalt sheet of Table mountain. Represents a confused mingling of dense and scoriaceous lava, presumably near edge of flow (No. 41).

391. Table mountain, Golden, Colorado. Shows effect of unequal, horizontal tabular jointing in dense part of a thick basalt sheet (No. 43).

392. Spherical sundering in cliff of basalt, northern Table mountain, Golden, Colorado. The most distinct spheres are from 1 to 2 feet in diameter, with several concentric shells (No. 1).

393. Granite cut by veins of quartz, feldspar, and biotite. In the canyon of Animas river, opposite Tenmile creek, Colorado, on railroad track (No. 453).

394. View of Silverton from toll road at east base of Sultan mountain. Shows Animas flood plain, mouth of Mineral and Cement creeks, etcetera, Colorado (No. 465).

395. From bench (with cabin) at 11,000 feet, on north side of McIntyre gulch; looking across Red Creek valley, southeast. Shows landslide topography of ridge, north of Corkscrew gulch, Colorado (No. 473).

396. From knoll near cabin at mouth of Galena Lion gorge; looking east across Red creek; to show details of landslide topography on slope between Corkscrew gulch and Red mountain, Colorado (No. 475).

397. View from knoll at mouth of Gray Copper gulch; looking north down length of Ironton park, Colorado; Saratoga mine buildings on the right (No. 481).
398. From bench at 11,500 feet north of Full Moon gulch, Colorado; looking down valley of Red creek; cliffs on San Juan tuff on the left (No. 481).
399. Rock glacier of Silver basin, from talus slope on east side of basin. Shows relation of glacier to basin. Caribou mine, Colorado (No. 485).
400. Potosi peak from Silver basin; looking north across Canyon creek (No. 488).

Photographed by N. H. Darton

8 by 10 inches. Negatives in United States Geological Survey

401. Dakota sandstone and Lakota sandstone through upper gateway to Perry park, south of Denver, Colorado; looking east (No. 779).
402. Vertical Red beds in Perry park, Colorado; looking south (No. 778).

Photographed by W. H. Jackson, Detroit, Michigan

20 by 43 inches

403. Pike's peak from the Garden of the Gods. Mounted, $12.00; not mounted $10.00 (No. 1008).

Photographed by J. K. Hillers

11 by 14 inches

404. Garden of the Gods, Colorado (no negative).

Photographed by I. C. Russell, 1888

6½ by 8½ inches. Negatives in United States Geological Survey

405. Triassic sandstone, Garden of the Gods, Colorado (No. 288).
406. Triassic sandstone, Garden of the Gods, Colorado (No. 289).

Photographed by N. H. Darton, 1898

6½ by 8½ inches. Negatives in United States Geological Survey

407. Triassic conglomerate sandstone, Garden of the Gods, Colorado (No. 424).
408. Cathedral spires, Garden of the Gods, Colorado (No. 430).

Photographed by C. D. Walcott

6½ by 8½ inches. Negative in United States Geological Survey

409. Contact of Silurian sandstone on pre-Paleozoic gneiss and schists; looking north from below the spring west of the Harding sandstone quarry, northwest of Canyon City, Colorado (No. 151).

Photographed by I. C. Russell, 1888

6½ by 8½ inches. Negative in United States Geological Survey

410. Monoclinal ridge, Colorado City, Colorado; Triassic and Jurassic (No. 291).

Photographed by J. F. Kemp, Columbia University, New York, New York

5 by 8 inches

411. View of mount Sopris, western Colorado, from the Spring Gulch coal mines across Jerome park. The point of view is on the Laramie. The intervening upturned strata are Mesozoic and Paleozoic.

412. The Sunshine coal mines, Jerome park, northwestern Colorado. The Laramie sandstones show in section on the right, dipping westward.

Photographed by G. K. Gilbert

5 by 8 inches. Negatives in United States Geological Survey

413. Group of Tepee buttes north of Nepesta, Pueblo county, Colorado (No. 859.)

414. Tepee butte; core not exposed; 2 miles northeast of Boone, Colorado (No. 940).

415. Exposed core of a Tepee butte north of Nepesta, Colorado (No. 941).

416. The Great Plains. Characteristic landscape on broad upland between the Platte and Arkansas rivers, Colorado (No. 942).

417. The Great Plains, Colorado. Spring issuing from the "Tertiary grit" (Hay) irrigates a few acres and affords water for cattle (No. 943).

418. Haystack butte, Pueblo county, Colorado. A typical mesa butte. Geologically an outlier of the Niobrara limestone protecting upper Benton shales. Lakelet basin in foreground, hollowed by wind erosion (No. 944).

419. End view of South Rattlesnake butte, an outlier of Niobrara limestone, Huerfano county, Colorado (No. 860).

420. Side view of North Rattlesnake butte, Huerfano county, Colorado. A remnant of Niobrara limestone capping a pyramid of upper Benton shale. The trees are juniper, from 10 to 12 feet high (no negative).

421. Typical water-pocket near Thatcher, Colorado. Timpas creek has here made a canyon 50 feet deep in Dakota sandstone (No. 945).

422. The Greenhorn formation, Middle Benton, exposed in an arroyo near Thatcher, Colorado. The upland at the right is capped by Niobrara limestone. The formation consists of a rapid alternation of limestone and shale, indicating a rhythm in the conditions of sedimentation (No. 946).

423. A cliff determined by a fault, Las Animas county, Colorado. The hard rock at the right is Dakota sandstone, originally covered by Benton shale. The plain at the left consists of Benton shale underlain by Dakota sandstone. The fault line follows base of cliff, and the block at the left stands about 200 feet lower than the block at the right. The country has been greatly degraded since the faulting, and the cliff results immediately from the unequal erosion of soft shale and hard sandstone (No. 947).

424. Modern rain-prints, natural size. Dried mud from Great Plains, Colorado. Animal tracks also shown (No. 948).

425. Ant hill, Pueblo, Colorado (No. 949).

Photographed by Frederick H. Chapin, Hartford, Connecticut

5 by 8 inches

Published in part as illustrations of "Mountaineering in Colorado," 1890. Mr Chapin's photograph numbers are given in parentheses.

426. Pikes peak, Colorado; looking northwestward from timber line on Bald mountain (No. 267).
427. Longs peak, Colorado; looking north-by-west from Table mountain (No. 25).
428. Longs peak, Colorado; lateral moraine (No. 36).
429. Longs peak, Colorado; view from Trough, looking northwestward. Fissured granite in right foreground (No. 15).
430. Longs peak, Colorado; view from Trough, looking westward (No. 14).
431. Longs peak, Colorado; lake and Lily mountain, looking eastward (No. 50).
432. Uncompahgre peak, Colorado, from the west on the divide (No. 350).
433. In the San Juan mountains; looking southwest-by-west toward Lone cone from the summit of Uncompahgre (No. 361).
434. View from the summit of Uncompahgre; looking westward (No. 345).
435. Arete of mount Snaefel; San Juan mountains, Colorado (No. 352).
436. Ypsilon peak, from Deer mountain, Estes park; looking westward (No. 210).
437. Ypsilon peak, Front range, Estes park (No. 214).
438. Estes park, Colorado; view looking northwest (No. 183).
439. Estes park, Colorado; view looking westward (No. 62).
440. Estes park, Colorado; view looking eastward (No. 90).
441. Acowitz canyon, Colorado; looking southwest (No. 438).
442. Alamo ranch and the Mesa Verde, point Lookout, near Mancos, Colorado (No. 405).
443. The Cliff palace, Cliff canyon, Mesa Verde, Colorado (No. 447).
444. The Cliff palace, Cliff canyon, Mesa Verde, Colorado (No. 456).

Photographed by Horace B. Patton, Golden, Colorado

6½ by 8½ inches

445. Effects of rain erosion on horizontally bedded andesite conglomerate. Headwaters of Rio Grande river, Colorado (No. 219).
446. Effects of rain erosion on horizontally bedded andesite conglomerate. Headwaters of Rio Grande, Colorado (No. 222).
447. Effects of rain erosion on horizontally bedded andesite conglomerate. Headwaters of Rio Grande, Colorado (No. 223).
448. Effects of rain erosion on horizontally bedded andesite conglomerate. Headwaters of Rio Grande, Colorado (No. 225).
449. Effects of rain erosion on horizontally bedded andesite conglomerate. Headwaters of Rio Grande, Colorado (No. 226).

CONNECTICUT

Photographed by W. H. Pynchon, Hartford, Connecticut

4 by 5 inches

450. Contact of Triassic conglomerate on underlying crystalline rock (schist). The locality is on Roaring brook, about 2½ miles west of Southington,

Connecticut, and is on the line of the western boundary of the Triassic area of Connecticut. The upright slabs of rock in deep shadow and the rocks over which the brook flows are schist. The massive overhanging brow is Triassic conglomerate (No. 1).

451. Detail of same locality as shown in 450 (No. 2).
452. City stone pit, Hartford, Connecticut, showing contact of trap sheet (probably the "posterior") on the underlying shales (No. 5).
453. Slab of Triassic sandstone, showing mud cracks; size about 10 feet by 5 feet; Shaler and Hall quarry, Portland, Connecticut (No. 6).
454. Section of the bed of volcanic ashes west of the southern end of Lamentation mountain, near Meriden, Connecticut. (See "The Lost Volcanoes of Connecticut." W. M. Davis. Popular Science Monthly, 1891.) The picture shows the flattened "bombs" imbedded in the ashes (No. 7).
455. Detail of a part of same ash-bed, showing bombs imbedded in the ashes (No. 8).

DELAWARE

(See Pennsylvania and Delaware)

DISTRICT OF COLUMBIA

(See Maryland and District of Columbia)

EUROPE

Photographed by Frank D. Adams, Montreal, Canada

4 by 5 inches

456. Embankment of river Po, near Ponte Lago Scuro. Right bank. From the plain, looking west.
457. Embankment of river Po, near Ponte Lago Scuro. Right bank. From same point as number 1, looking east.
458. General view of embankment, taken from point half way up its side, with Ponte Lago Scuro and railway bridge in distance. Shows the three terraces of the embankment.
459. View across the Po from summit of embankment on south side. Buildings of S. M. Maddalena on northern side partially hidden behind the embankment in front of them.

HAWAIIAN ISLANDS

Photographed by William Libbey, Jr., Princeton, New Jersey

6½ by 8½ inches

460. Hawaii. Peepee falls, near Hilo (No. 58).
461. Hawaii. Down the gorge from the "pots" (No. 60).
462. Hawaii. Rainbow falls, on the Wailuku (No. 57).
463. Hawaii. Lava tree (No. 70).
464. Hawaii. Lava trees showing structure, Puna (No. 68).

465. Hawaii. Lava stalactites, flow of 1881, Bougainville (No. 56).
466. Hawaii. Mauna Loa from Hilo, 35 miles distant (No. 46).
467. Hawaii. Panorama of Kilauea from volcano house, with steam issuing from fissures (No. 75).
468. Hawaii. First fissure. Edge of Kilauea (No. 85).
469. Hawaii. Edge of Kilauea. First landslip (No. 84).
470. Hawaii. Fissure back of sulphur banks (No. 85*a*).
471. Hawaii. Waldrous ledge; highest part of edge of Kilauea (No. 77).
472. Hawaii. Flow of 1868, on isthmus between Kilauea and Kilauea isli. Tree in lava (No. 87).
473. Hawaii. Surface flow; Halemanman (No. 98).
474. Hawaii. Halemanman; lava surface (No. 99).
475. Hawaii. Halemanman; rim of active portion (No. 100).
476. Hawaii. Lava flow from side of active portion (No. 102).
477. Hawaii. Keanalsakoi; small crater, 500 feet deep, near Kilauea (No. 86).
478. Hawaii. Fissure, looking east (No. 91).
479. Hawaii. Bubble, Kilauea (No. 92).
480. Hawaii. Bubble, Kilauea (No. 94).
481. Hawaii. Spatter cone, Kilauea (No. 93).
482. Hawaii. Hut on edge of Halemanman. Destroyed in March, 1894 (No. 95).
483. Hawaii. Active portion of Halemanman; 1,000 feet in diameter (No. 96).
484. Hawaii. Inside the active portion of Halemanman (No. 104).
485. Hawaii. Inside cauldron; Halemanman (No. 105).
486. Oahu. The punch bowl from mount Tantalus (No. 15).
487. Oahu. The Pali (No. 1).
488. Maui. On the road to Haleakala (No. 106).
489. Maui. Cloud effect on summit of Haleakala (No. 113).
490. Kauai. Valley of Kipukai; general view of house and valley (No. 126).
491. Maui. Rim of crater to southeast; outside (No. 112).
492. Maui. Inside crater of Haleakala (No. 116).
493. Maui. On floor of crater of Haleakala; looking to the northeast; highest point (No. 114).
494. Kauai. Valley of Haualei (No. 133).

IDAHO

Photographed by J. F. Kemp, Columbia University, New York, New York

5 by 7 inches

495. Terraces of Tertiary lake-beds, near Salmon City, Idaho, on the Lemhi river.
496. Terraces of Tertiary lake-beds, on Lemhi river, near Salmon City, Idaho.
497. Old gold diggings, on Napias creek, Leesburg, Idaho, worked from 1859 to 1865.
498. Rocky cut for sluice, California bar, Idaho.
499. Discharge sluice, California bar.
500. Hydraulic mining at California bar.

Photographed by C. D. Walcott

5 by 7 inches. Negatives in United States Geological Survey

501. Basal Cambrian sandstones of section at mouth of Two-mile canyon, 2 miles south of Malad City, Idaho (No. 562*a*).

ILLINOIS

Photographed by O. C. Farrington, Field Columbian Museum, Chicago, Illinois

5 by 7 inches

502. Drift, section 5, Chicago drainage canal. Shows sudden transition from coarse drift to fine sand; also highly inclined bedding (No. 2).
503. Drift, section 5, Chicago drainage canal. 200 feet below number 502. Drift very coarse; boulders are limestone (No. 3).
504. Section of kame, showing drift, Chicago drainage canal (No. 5).
505. Drift on limestone, section 6, Chicago drainage canal. The upper surface of the limestone is broken and shattered at the contact with the drift, apparently by resistance to glacial movement. The resistance was also unequal, part of the limestone near the contact at the right having been entirely carried away. The direction of glacial movement was from left to right (No. 7).
506. "Clay pocket," section 7, Chicago drainage canal. The limestone has undergone differential internal disintegration, causing portions of the strata to fall and become tilted. The section is 36 feet in height (No. 8).
507. "Clay pocket," section 10, Chicago drainage canal. The hollow formed in the limestone by disintegration has been filled from above by drift (No. 9).

INDIANA

Photographed by F. V. Marsters

508. Indiana oolitic stone quarry, Steinsville, Indiana.
509. Weathering of Indiana oolitic limestone, near Herodsburgh, Indiana.
510. Hunter's quarry (Saint Louis limestone), Bloomington, Indiana.
511. Johnson's quarry, Bloomington, Indiana.
512. End View. Largest block of stone (Indiana limestone) quarried up to September, 1893. Size, 11′ 9″ by 8′ 8″ by 10′ 4″; 1,054 cubic feet; weight, 190,000 pounds; quarried by Bedford Stone Company, Bedford, Indiana.

Photographed by W. P. Jenney

6½ by 8½ inches. Negatives in United States Geological Survey

513. Anticline at termination of Ozark uplift in northeast corner of Indian Territory, on Spring river, about 6 miles south of Baxter, Kansas. Panorama of 4 negatives, Nos. 183, 184, 185, and 186.

INDIAN TERRITORY

Photographed by J. E. Taff, 1899

4 by 5 inches. Negatives in United States Geological Survey

514. Faulted sandstone and shale, Kansas City, Pittsburg and Gulf railway, 1 mile southeast of Houston (No. 64).
515. Faulted sandstone and shale, Kansas City, Pittsburg and Gulf railway, 1 mile southeast of Houston (No. 34).
516. Faulted sandstone and shale, Kansas City, Pittsburg and Gulf railway, 1 mile east (No. 35).
517. Recumbent fold in sandstone, Saint Louis and San Francisco railway, south base of Winding Stair mountain (No. 31*a*).
518. Faulted sandstone and shale, Kansas City, Pittsburg and Gulf railway, 1 mile southeast of Houston (No. 63).
519. Recumbent fold in sandstone, Saint Louis and San Francisco railway, south base of Winding Stair mountain. Panorama (No. 31*b*).

IOWA

Photographed by the Geological Survey of Iowa

5 by 8 inches

520. Cross-bedding in Coal Measures sandstone; Redrock, Marion county (No. 79).
521. Gypsum quarry face; Cretaceous; Iowa Plaster Company, Fort Dodge, Webster county (No. 83).
522. Dakota formation, showing clays, lignite and sandstone, capped by loess; Sargeants bluff, Woodbury county, Iowa (No. 87).
523. Chalk cliff; Niobrara; on Sioux river, Old Crills mill, below Westfield, Plymouth county (No. 89).
524. Floodplain of the Missouri; view taken from high bluffs east of the Sioux river; showing that river at the base; Dakota lowland between it and the Missouri, with the Nebraska hills south of the Missouri in the distance; Old Crills mill, below Westfield, Plymouth county, Iowa (No. 102).
525. Glacial scorings; Kingston, Des Moines county (No. 106).
526. Till interbedded in loess; sand pits north of Sioux City, Woodbury county, Iowa. The hammer points to a boulder of Sioux quartzite (No. 111).
527. Quarry in Devonian limestone; Cedar Valley stage; showing two parallel joints. Near Iowa City, Johnson county, Iowa (No. 124).
528. Columns of Saint Croix sandstone; Lane's farm; T. 100 N., R. 4, Sec. 31 (No. 10).
529. Exposure of Leclaire limestone, obliquely bedded below, horizontally bedded above. Sugar Creek lime quarries, Cedar county, Iowa (No. 142).
530. Oblique bedding in Leclaire limestone, half a mile south of Leclaire, Iowa. The soil at top of exposure is an ancient shell heap or kitchen-midden (No. 145).
531. Exposure of thin bedded Leclaire limestone, Leclaire, Iowa, showing effect of subaquatic erosion and subsequent deposition of similar limestone in eroded trough (No. 146).

532. View in Cedar Valley quarry. Anamosa stage of Niagara limestone, Cedar Valley, Iowa (No. 147).

533. The Buchanan gravels, an interglacial, probably Aftonian deposit of water-laid, cross-bedded sands and gravels. The boulders in foreground have been thrown out of the gravel, and are of the Kansan drift type. The gravels are overlain by a thin layer of Iowan drift with numerous large granite boulders (see number 151) (No. 149).

534. Granitic boulders of Iowan drift near Winthrop, Iowa (No. 150).

535. View in Champion quarry, Stone City, Iowa; Anamosa stage of Niagara (No. 144).

536. Mount Hope; a hill of circumdenudation standing on a baseleveled plain; composed of Saint Croix overlain by Oneota; from south side of Oneota river; T. 100, R. 5, Sec. 34 (No. 14).

537. Saint Peter sandstone, showing weathering effects; T. 96, R. 5, Sec. 14, S. W. ¼ N. W. ¼ (No. 31).

538. Beds of passage between Niagara limestone and Maquoketa shale; T. 90, R. 4, Sec. 10; Delaware county, Iowa. Photographed by Calvin (No. 56).

539. Niagara overlying Maquoketa, illustrating the effects of geologic structure on topographic form within the driftless area; the gently undulating lower slopes are underlain by the Maquoketa shale; the steep hills in the background are constructed of the overlying Niagara limestone; view looking south from Lattners, near Graf, Dubuque county, Iowa (No. 58).

540. Stairway at "Devils Backbone," illustrating effects of weathering on Niagara limestone; northwestern part of Delaware county, Iowa (No. 64).

541. Cross-bedding in sandstone; Saint Louis; Bellefontaine, Makaska county, Iowa (No. 75).

542. Steffen's quarry, Cleona township, Scott county, Iowa. Pitted rock surface beneath Kansan drift. False bedding of Leclaire limestone. Iowa Geological Survey, volume ix (No. 6).

543. Mount Vernon paha from south. Iowa Geological Survey, volume iv, pages 181-184 (No. 12).

544. Paha between Mount Vernon and Lisbon, Iowa (No. 13).

545. South of Cedar river, Linn county, Iowa. Ultimate ramification of dendritic drainage on loess mantle of Kansan drift sheet. Cedar Rapids sheet, U. S. Geological Survey (No. 1).

546. Erosion gullies in loess mantle on Illinoian drift sheet, Princeton township, Scott county. Iowa Geological Survey, volume ix (No. 17).

547. Swallows' nests in loess, Clinton, Iowa (No. 19).

548. Lingulate lobes of heavy loess near Iowan frontier, northwest of Princeton, Scott county, Iowa. Iowa Geological Survey, volume ix (No. 20).

549. Topography of Kansan drift sheet, showing slopes of larger ravines. South of Cedar river, Linn county, Iowa. Cedar Rapids sheet, U. S. Geological Survey (No. 2).

550. Wide floodplain of Wapsipinicon river, Scott county, Iowa; seen from roadway cut in loess-mantled hills of Iowan frontier. Leclaire sheet, U. S. Geological Survey; Iowa Geological Survey, volume ix (No. 24).

551. Broad valley of Cedar river below gorge south of Mount Vernon, Iowa. Mechanicsville sheet, U. S. Geological Survey (No. 26).

552. Contact of Niagara limestone (Silurian) and Hudson River shales (Ordovician). Above Lyons, Iowa (No. 30).

553. Topography of Kansan drift sheet loess-mantled spatulate gullies. South of London, Cedar county, Iowa (No. 3).
554. Chert layers in Delaware beds. Niagara limestone, Lyons, Iowa. Banks of Mississippi river (No. 32).
555. Unstratified mound in Leclaire limestone (Anamosa type), near Lowden, Iowa (No. 38).
556. Leclaire limestone near Massillon, Iowa. Illustrating the breaking down of cliffs along joint planes (No. 39).
557. Ferruginous stains. Slab of Anamosa limestone, Leclaire stage of Niagara, from Mount Vernon quarry, Iowa (No. 40).
558. Bieler's quarry, Cedar Valley, Iowa, showing horizontal and even bedding of Anamosa stone. Leclaire stage of the Niagara (No. 41).
559. The Lower Davenport beds. Devonian. Mouth of Duck creek, Scott county, Iowa. See Geology of Scott county, Iowa Geological Survey, volume ix (No. 45).
560. Breccia in Lower Davenport beds, Rock Island, Illinois. Initial flexures (No. 48).
561. Breccia, Linn, Linn county, Iowa. Lowest phase, natural size. Iowa Geological Survey, volume iv, pages 157–166 (No. 50).
562. Breccia, Linn, Linn county, Iowa. Close view. Complex brecciation in large fragments. Iowa Geological Survey, volume iv, pages 157–166 (No. 52).
563. Breccia, Linn, Linn county, Iowa. Illustrating differential weathering of breccia, largely made up of Independence shales forming abundant talus and breccia consisting of numerous fragments of Lower Davenport limestone, with sparse matrix. Iowa Geological Survey, volume iv, pages 157–166 (No. 53).
564. Kansan-loess topography, showing even sky-line and spatulate valleys. Dixon, Scott county, Iowa. On farm of Ketelson. Iowa Geological Survey, volume ix (No. 57).

KENTUCKY

Photographed by Ben. Haines, New Albany, Indiana

8 by 10 inches. Price, 50 cents each

Views of Mammoth cave and vicinity

565. Standing rocks (No. 08).
566. The post-oak pillar (No. 022).
567. The arm-chair (No. 029).
568. The Egyptian temple (No. 036).
569. Star chamber (No. 057).
570. White's cave; Humboldt's pillar (No. 0101).
571. White's cave; the royal canopy (No. 0106).
572. Wyandotte cave; Niagara falls (No. 1) (No. 235).
573. First saltpeter vats (No. 04).
574. Old saltpeter pipes (No. 05).
575. Stone cottage (No. 013).

576. Giant's coffin (No. 014).
577. The elephants' heads (No. 030).
578. Bacon chamber (No. 037).
579. Stalactites in Croghan's hall (No. 055).
580. End of the cave (No. 056).
581. An alcove in Gothic avenue (No. 060).
582. Head of Echo river (No. 065).
583. Mammoth Cave hotel (No. 0124).
584. Wyandotte cave; the throne (No. 218).
585. Wyandotte cave; Monument mountain and Wallace's grand dome (No. 220).
586. Marengo cave; "Cupid's net" (No. 524).
587. Marengo cave; Washington's plume (No. 529).

MAINE

Photographed by S. R. Stoddard, Glens Falls, New York

5 by 8 inches. Price, 30 cents each

588. Mount Desert island, looking southwestward from Green mountain (No. 1246).
589. Eagle lake, Mount Desert island, looking northwestward (No. ?).

Photographed by G. P. Merrill, United States National Museum

5 by 8 inches

590. Granite quarry, Hallowell, Maine (No. ?).

Photographed by J. F. Kemp, Columbia University, New York, New York

6½ by 8½ inches. Price, 12 cents each

591. Vertical schists, quartzites, etcetera, with trap dikes, at Bald cliff, Maine (No. ?).

MARYLAND AND DISTRICT OF COLUMBIA

Photographed by N. H. Darton

6½ by 8½ inches. Negatives in United States Geological Survey

592. Earlier Columbia gravels and loam in street cut in western part of Baltimore, Maryland (No. 55).
593. Gravel bed and loams of earlier Columbia, on weathered crystalline rocks, in north side of cut of railway just east of Rock Creek bridge, Washington, D. C. (No. 80).
594. Earlier Columbia gravel bed and loams on crystalline rocks in cut of railway just east of Rock Creek bridge, Washington, D. C.; exhibiting a fault. Looking north (No. 79).
595. Lafayette gravels and loams lying on Chesapeake sands near northwest entrance of Soldiers Home, Washington, D. C.; looking north (No. 86).

596. Chesapeake sands, Matawan clays, and Potomac sands in road cut half a mile southwest of Good Hope, District of Columbia. The blade of the hammer is at the Chesapeake-Matawan contact, the position of which is also indicated by the arrows to the right. The Matawan-Potomac contact is three feet below and is clearly exhibited. The Pamunkey formation is absent (No. 73).
597. Shell beds in Chesapeake formation on west side of Patuxent river, at Jones' wharf, Saint Marys county, Maryland (No. 51).
598. Cliffs of Chesapeake sands and clays surmounted by Lafayette gravelly sands, Plum point, Calvert county, Maryland; looking south (No. 61).
599. Matawan formation on east side of Gibson island, Magothy river, Anne Arundel county, Maryland. Shows characteristic silicious concretions in place and along the shore (No. 215).
600. Cliffs of Potomac clays, Wortons point, Kent county, Maryland (No. 206).
601. Ferruginous concretions in sand of Potomac formation in road cuts on Patterson estate, northeastern Baltimore, Maryland (No. 219).
602. Sands, gravels, and clays of Potomac formation in cut of Belt Line railroad, just east of Belair road, northeastern Baltimore, Maryland (No. 218).
603. Columbia formation on crystalline schists near N and Twenty-fourth streets N. W., Washington, D. C. (No. 278).
604. Columbia formation, basal beds, near N and Twenty-fourth streets N. W., Washington, D. C. (No. 282).

Photographed by J. K. Hillers

11 by 14 inches. Negatives in United States Geological Survey

605. Wild Duck bluff, Chesapeake bay (no negative).
606. Unconformity between Columbia and Potomac formations, Chesapeake bay (No. 336).
607. Turkey point (No. 338).
608. Center of Grove point, Chesapeake bay (No. 335).
609. Section at Howell's point, Chesapeake bay (no negative).
610. Near East Capitol street, between Sixteenth and Seventeenth, Washington, D. C. Columbia loam, as excavated for brick-clay, and terrace plain formed by it. Natural surface. Looking southwest (No. 346).
611. Columbia and Potomac formations, Forrest place, north side of Chase street, Baltimore, Maryland (No. 325).
612. Formation of gravel from vein quartz. South side of Oakland street, 200 yards west of Columbia road, Kalorama heights, Washington, D. C. (no negative).
613. Looking up Susquehanna river from Baltimore and Ohio railroad bridge (No. 340).
614. Columbia formation on Potomac formation in Wild Duck bluff, head of Chesapeake bay, Maryland (No. 337).

Photographed for N. H. Darton

6½ by 8½ inches. Negatives in United States Geological Survey

615. The Potomac near Harpers Ferry (No. 235).
616. Junction of the Shenandoah and Potomac rivers (No. 236).

617. The Shenandoah near Harpers Ferry (No. 237).
618. The Great falls of the Potomac (No. 238).

MASSACHUSETTS

Photographed by George P. Merrill, United States National Museum

6½ by 8½ inches

619. Marine erosion of till, Long Island head, Boston harbor (No. —).
620. Ship rock, Massachusetts. A glacial-drift boulder at Peabody. This boulder is 51 feet long, 27 feet wide, and 31 feet high. View from the north. The source is probably local (No. —).
621. *Roche moutonnée*, Marblehead, Massachusetts (No. —).
622. Marine erosion of till, Boston harbor. Cliff on eastern edge of Great Brewster islands (a drumlin) (No. —).

Photographed by S. R. Stoddard, Glens Falls, New York

5 by 8 inches. Price, 50 cents each

623. Monomoy point; looking northward from Monomoy light-house, Cape Cod. Massachusetts (No. 1207).
624. The "powder-hole," Monomoy light-house, from the light-house (No. 1206).

MEXICO

Photographed by O. P. Farrington, Field Columbian Museum, Chicago, Illinois

5 by 7 inches

625. Porfirio Diaz glacier, Ixtaccihuatl, Mexico, from the old terminal moraine (No. 12).
626. Weathering of quartz vein near El Bote mine, Zacatecas, Mexico. The surrounding rock is chlorite schist (No. 13).
627. Section of lava flow, El Pedregal of Tialpam, near San Angel, valley of Mexico. The vesiculation of the lava by escaping vapors is shown and the increase through relief of pressure in the size of the vesicles toward the upper surface (No. 14).

MICHIGAN

Photographed by I. C. Russell, 1887

8 by 10 inches. Negatives in United States Geological Survey

628. Sea-cliff in limestone, Mackinaw island, Michigan (No. 174).
629. Sea-cliff in sandstone, small island near Marquette, Michigan (No. 167).

Nos. 630, 631, 635, 638, 640, 641, 643 are published by G. K. Gilbert in Fifth Annual Report U. S. Geological Survey.

630. Sea-cliff in hard sandstone, with beach beyond, Au Train island, lake Superior (No. 172).

631. Sea cliff in boulder clay, with beach in foreground, South Manitou island, lake Michigan (No. 129).
632. Sea-cliff in sand, with beach, Sleeping Bear point, eastern shore of lake Michigan (No. 111).
633. Sea-cliff in boulder clay, South Manitou island, lake Michigan (No. 113).
634. Sea-cliff in boulder clay, North Manitou island, lake Michigan (No. 134).
635. Beach of limestone pebbles, Mackinaw island, Michigan (No. 158).
636. Gravel spit, with driftwood, near Mackinaw island, Michigan (No. 161).
637. A spit forming under water, western end of Bois Blanc island, Michigan; Mackinaw island in the distance (No. 148).
638. Spit of shingle, Au Train island, lake Superior (No. 168).
639. Curved sand spit, southern channel, strait of Mackinaw (no negative).
640. A recurved spit, "Duck point," Grand Traverse bay, lake Michigan (No. 102).
641. Bar joining Empire and Sleeping Bear bluffs, eastern shore of lake Michigan (No. 114).
642. Ancient sea-cliff of lake Michigan, near Glen Arbor, Michigan (No. 106).
643. Ancient sea-cliff of lake Michigan, South Manitou island, lake Michigan (No. 137).
644. Sand dunes near Sleeping Bear bluff, eastern shore of lake Michigan (No. 109).
645. Forest formerly buried beneath drifting sand and now exposed by eolian erosion. High part of South Manitou island, lake Michigan (No. 131).

MINNESOTA

Photographed by J. F. Kemp, Columbia University, New York, New York

5 by 7 inches

646. Open cut at iron mines of the Minnesota company near Tower, Minnesota.
647. Sunken ground over the Chandler mine, Ely, Minnesota.
648. Oliver mine, Virginia, Minnesota; entering cut, upper bench gravel, lower bench ore.
649. Working face of the Mountain iron mine, Minnesota.
650. Working face of the Mountain iron mine, Minnesota.
651. Surface panorama of Canton mine, Mesabi range, Minnesota.
652. Caved surface of Canton mine, Mesabi range, Minnesota.

MISSOURI

Photographed by E. L. Furguson

6½ by 8½ inches

653. A western Missouri coal mine.

Photographed by J. F. Kemp, Columbia University, New York, New York

5 by 7 inches

654. Open cut and stopes at Pilot knob, Missouri, showing the relations of the specular hematite to the porphyry, and also the thickness of the ore body.

MONTANA

Photographed by W. H. Weed

4 by 5 inches. Negatives in United States Geological Survey

655. Amphitheater at head of Little Timber creek (No. 4).
656. Lake at head of Little Timber creek; occupies a rock basin (No. 2).
657. Laramie conglomerate; formed of pebbles of volcanic rocks (No. 1).
658. Morainal debris; characteristic of mountain moraine of Crazy mountains, Montana (No. 3).

Photographed by J. F. Kemp, Columbia University, New York, New York

5 by 7 inches

659. Contact of basic granite (left side) and acid granite (Bluebird granite) intended in former cut on Butte, Anaconda and Pacific railroad, Butte, Montana.
660. The Parrot and Anaconda mines, Butte, Montana, with bounding ranges on east.
661. The Lexington mine, Butte, Montana.

Photographed by C. D. Walcott

5 by 7 inches. Negatives in United States Geological Survey

662. Missouri River beds above railroad bridge, near Townsend, Montana (No. 523).
663. Hogback, formed by upturned basal Cambrian sandstone (Flathead), Indian creek, 4 miles west of Townsend, Montana (No. 525).
664. Hogback, formed by upturned basal Cambrian sandstone (Flathead), Indian creek, 4 miles west of Townsend, Montana (No. 525*a*).
665. Slaty shales in which pre-Cambrian fossils were found, mouth of Deep Creek canyon, 16 miles east of Townsend, Montana (No. 527*b*).
666. Eroded Carboniferous sandstones in cliff 8 miles south of Livingston, Montana, west of Yellowstone river (No. 534*a*).
667. Eroded Carboniferous sandstones in cliff 8 miles south of Livingston, Montana, west side of Yellowstone river (No. 534*b*).
668. Eroded Carboniferous sandstones in cliff 8 miles south of Livingston, Montana, west side of Yellowstone river (No. 534*c*).
669. Eroded Carboniferous sandstones in cliff 8 miles south of Livingston, Montana, west side of Yellowstone river (No. 535*c*).
670. View looking north from Point of Rocks down Yellowstone valley, about 34 miles south of Livingston, Montana (No. 539).
671. Carboniferous on north side of Beaver creek, above Missouri river, Big Belt mountains, Montana (No. 537).

6½ by 8½ inches

672. Lower Paleozoic section in cliffs, north side of canyon, north fork of Dearborn river, Lewis and Clarke county, Montana (No. 657).

673. Carboniferous limestone cliff of mount Dearborn, north fork of Dearborn river, Lewis and Clarke county, Montana (No. 659).
674. Haystack butte from the east, with hay ranch in the foreground. A typical volcanic neck (No. 670).
675. Mount McDonald from the east, Mission range, Montana (No. 673).
676. Glaciers on Mission range, southeast of mount McDonald, Montana (No. 674).
677. Eroded, cross-bedded Cretaceous sandstone, north of the north fork of Sun river, 1 mile east of Rocky mountain front, Teton county, Montana (No. 629*a*).
678. Eroded, cross-bedded Cretaceous sandstone, north of north fork of Sun river, 1 mile east of Rocky mountain front, Teton county, Montana (No. 629*c*).

NEBRASKA

Photographed by N. H. Darton

6½ by 8½ inches. Negatives in United States Geological Survey. Published in Nineteenth Annual Report United States Geological Survey, Part 4

679. Conglomeratic sandstone lens in Brule clay 5 miles south from Gering, Scotts Bluff county, Nebraska (No. 343).
680. Arikaree conglomerate lying on Arikaree sands 10 miles southeast from Gering, Banner county, Nebraska. Looking northwest (No. 344).
681. Scotts Bluff, Scotts Bluff county, Nebraska. From north side of North Platte river, 3 miles distant. "Dome rock" in the distance. Arikaree and Gering formations on Brule clay, 3 miles northwest of Gering (No. 348).
682. Bad lands in Brule clay on south slope of Scotts Bluff, Scotts Bluff county, Nebraska. Looking northeast (No. 355).
683. Bad lands just north of Scotts Bluff, Scotts Bluff county, Nebraska. Looking north to and beyond the North Platte river. Shows remnant of plain from which Bad lands have been formed. In Brule clay (No. 358).
684. Blowout with core 3 miles south of Harrison, Nebraska. Arikaree formation. Daemonelix beds (No. 363).
685. Daemonelix beds in Arikaree formations near head of Little Monroe canyon, Sioux county, Nebraska. Looking northeast (No. 364).
686. Typical sand hills 15 miles north from camp Clarke, Nebraska. Showing smooth leaward slopes. Looking northwest (No. 365).
687. Typical sand hills 15 miles north from camp Clarke, Nebraska. Showing blowouts characteristic of windward slopes. Looking southeast (No. 366).
688. "Toadstool park" 3 miles northwest from Adelia, Nebraska, Sioux county. Thin sandstone layers in clays of White River series (No. 368).
689. Spring and its saline deposits from Pierre shale 10 miles northwest of Chadron, Dawes county, Nebraska (No. 397).
690. Fault in Gering formation in cut of B. and M. railway one-half mile north of Rutland siding, south of Crawford, Nebraska. Looking west (No. 401).
691. Bad lands 6 miles northeast of Chadron, Dawes county, Nebraska. Brule sandy clay (No. 402).
692. "Toadstool park," Bad lands near Adelia, Sioux county, Nebraska (No. 443).
693. "Toadstool park," Bad lands near Adelia station (No. 444).
694. Looking down North Platte river at the Wyoming-Nebraska line (No. 445)

695. Titanotherium sands east of Adelia (No. 434).

696. Dakota sandstone with cross-subbedding, Bennett, Nebraska (No. 254).

697. Jail and court-house, Cheyenne county, Nebraska. Arikaree and Gering formations unconformable on Brule clay. Looking northwest (No. 310).

698. The jail, Cheyenne county, Nebraska. Gering formation unconformable on Brule clay. Looking east (No. 311).

699. "Chimney rock," Cheyenne county, Nebraska. The spire is of Gering sandstone. The slopes are of Brule clay, containing a bed of volcanic ash. Position of the volcanic ash indicated by horse. Looking west (No. 315).

700. Gering formation eroded by wind-blown sand 3 miles northeast from Freeport, Banner county, Nebraska (No. 327).

701. "Smokestack," Banner county, Nebraska. From the east. The smokestack is of Arikaree conglomerate, of which other fragments are to be seen farther back on same ridge. The base of the ridge is of Brule clay (No. 339).

702. "Smokestack." From the west. The smokestack is of Arikaree conglomerate, a fragment of an old river channel of Arikaree times (No. 341).

703. "Twin Sisters," Banner county, Nebraska. Shows Arikaree and Gering formations lying unconformably on Brule clay; also volcanic ash-bed in lower gap. Looking west (No. 342).

NEVADA

Photographed by I. C. Russell

8 by 10 inches. Negatives in United States Geological Survey

704. Lahontan lake-beds, bank of Humboldt river, Nevada (No. 6).

705. Hillside coated with calcareous tufa deposited from lake Lahontan, shore of Pyramid lake, Nevada (No. 11).

706. Calcareous tufa deposited from the waters of lake Lahontan, shore of Pyramid lake (No. 179).

707. Rocks coated with calcareous tufa, beach of oölitic sand. Shore of Pyramid lake. Published in Monograph xi, U. S. Geological Survey, plate xiii (No. 20).

708. Tufa domes formed by sublacustral springs. Published in Eighth Annual Report U. S. Geological Survey, plate xxi (No. 40).

709. An island of calcareous tufa deposited from the waters of lake Lahontan, Pyramid lake. Published in Monograph xi, U. S. Geological Survey, plate xxxviii (No. 21).

710. Sediments of lake Lahontan, Humboldt valley near Rye Patch, Nevada. Published in Monograph No. xi, U. S. Geological Survey, plate xxii. Size, 8 by 10 inches (No. 9).

711. Lithoid, thinolitic, and dendritic tufa deposited from the waters of lake Lahontan, shore of Pyramid lake (No. 13).

Photographed by H. W. Turner

6½ by 8½ inches. Negatives in United States Geological Survey

712. Monoclinal ridge capped by basalt at north end of Clayton valley (No. 68).

713. A single cone of rhyolite-tuff from the same locality as number 714, in the foothills of the Palmetto mountains (No. 77).

714. Group of cones formed by the unequal erosion of rhyolite-tuff in the foothills of the Palmetto mountains south of Clayton valley (No. 76).
715. Lacustral marls of the Esmeralda formation at the east base of the Silver Peak range south of the Emigrant road (No. 71).
716. Fault surface in the foothills of the Silver Peak range southwest of Clayton valley. The rock is rhyolite-tuff (No. 73).

New Hampshire

Photographed by George P. Merrill, United States National Museum, Washington, D. C.

6½ by 8½ inches

717. Churchill rock, Nottingham, New Hampshire. Glacial drift boulder, 62 feet long, 40 feet wide, and 40 feet high; source, local; view from southwest.
718. The Washington boulder. A glacial-drift boulder at Conway, New Hampshire. This is a very solid block of Conway granite. It cannot be shown to have been transported more than one mile. Its dimensions are 30 by 40 by 25 feet. View from the northeast.
719. The Bartlett boulder. A glacial-drift boulder at Bartlett, New Hampshire. This boulder is of the Conway granite, and rests on four smaller boulders of the same kind on the summit of a knoll of till projecting through the modified till.
720. Cathedral rock. Profile view from the northeast. North Conway, New Hampshire. The hills show the typical *roche moutonnée* outline.

New Jersey.

Photographed by N. H. Darton

5 by 8 inches. Negatives in United States Geological Survey

Published in Bulletin 67, United States Geological Survey

721. Base of first Watchung trap-sheet in gorge of Passaic river at Paterson, New Jersey, showing both basaltic columns and bedded trap in the same sheet and contact with Newark shales (No. 22).
722. Lateral ascent of base of palisade trap across Newark shales at Kings point, Weehawken, New Jersey. Shore of the Hudson river (No. 16).
723. Cross-section exposure of base of palisade trap-sheet, showing its contact with the Newark shales. West Shore railroad tunnel, Weehawken, New Jersey (No. 13).
724. Falls of the Passaic at Paterson, New Jersey. Edge of first Watchung trap-sheet (No. 19).

Photographed by S. R. Stoddard, Glens Falls, New York

5 by 8 inches. Price, 50 cents

725. Palisades of the Hudson; looking northward from Englewood cliffs.

Photographed by J. P. Iddings

6½ by 8½ inches. Negatives in United States Geological Survey

726. Columnar basalt, O'Rourke's quarry, Orange mountain, New Jersey. Converging column in middle of quarry. Described in American Journal of Science, third series, volume xxxi, 1886, pages 321–331 (No. 119).
727. The same, northern end of quarry (No. 118).
728. The same. Southern end, showing the curved, tapering ends of vertical columns and the junction of two groups of small columns (No. 117).
729. The same, showing converging columns and large vertical columns (No. 121).
730. The same, showing large vertical columns with spheroidal parting and transverse, chiseled structure (No. 123).
731. The same, another picture of the quarry (No. 122).
732. Intrusive basalt, showing columns of cooling, Orange quarry, New Jersey (No. 120).

Photographed by R. D. Salisbury, University of Chicago, Chicago, Illinois

8 by 10 inches

733. *Roche moutonnée* (trap), one mile east of Englewood, New Jersey, on Palisade avenue; showing broad, deep grooves.
734. Glaciated surface of trap exposed by the excavation for the reservoir at Weehawken, New Jersey. In addition to the glaciation of the surface, the photograph shows the phenomena of "plucking."
735. Perched block of Triassic sandstone, 12 by 8 by 8 feet, on Palisade ridge, east of Englewood, New Jersey, near the summit. Beneath the boulder the trap surface shows polishing and grooving, but where the surface has not been protected the polishing and grooves have disappeared by weathering. The boulder has probably been lifted 180 feet.
736. Glaciated surface of trap exposed by the excavation for the reservoir at Weehawken, New Jersey. In addition to the glaciation of the surface the photograph shows the phenomena of "plucking."

NEW YORK

Photographed by G. K. Gilbert

4 by 5 inches. Negatives in United States Geological Survey

737. Shore of lake Ontario, Griffin bay, New York. The waves have excavated a cliff from boulder clay, but have not been able to remove the larger boulders (No. 922).
738. Shore of lake Ontario, Griffin bay. A barrier of shingle separates a lagoon from the lake (No. 923).
739. On western shore of Cayuga lake, at East Varick, New York. A delta modified in outline through deflection of shore currents by a projecting pier (No. 924).
740. Views of Iroquois shore, near Wolcott, New York. A sea-cliff, cut from a drumlin, appears just to the right of the center, and a spit running to the left bears a house and barn (No. 925).

741. Portion of Iroquois shore, near Wolcott. The camera stands on a spit and is turned toward a sea-cliff cut from a drumlin (No. 926).

742. Iroquois shore, near Constantia, New York. The camera stands on a beach ridge of gravel. Compare modern beach in No. 123 (No. 914).

743. Iroquois shore, near Pierrepont manor, New York. Excavation of till by the waves left a cut terrace set with large boulders. Compare with No. 737 (No. 928).

744. Iroquois shore, near Pierrepont manor. Excavation of till by the waves left a cut terrace set with large boulders. Compare with No. 737 (No. 929).

745. Iroquois shore, section of spit, 3 miles east of Watertown, New York. The open lake lay at the left, a bay at the right. The spit was accumulated by additions on the landward side (no negative).

746. Wall composed of limestone blocks rounded by wave action on an ancient shore of lake Ontario, 5 miles east of Watertown (No. 931).

5 by 7 inches

747. Shore of lake Ontario, Niagara county, New York. Illustrates mode of origin of beach shingle by showing rock in place and angular rocks recently detached (No. 1743).

748. Beach of flat shingle. Shore of lake Ontario at Golden Hill creek, New York (No. 1744).

749. Beach of well rounded shingle. Shore of lake Ontario at Golden Hill creek, New York (No. 1745).

750. Cemented shingle in spit of glacial lake Iroquois at Lewiston, New York (No. 1746).

751. Section of spit of glacial lake Iroquois at Lewiston. The dip is landward, indicating growth on the inside of the spit (No. 1747).

752. Section of spit of glacial lake Iroquois at Lewiston. The dip is landward, indicating growth on the inside of the spit (No. 1748).

753. Cut terrace of the Iroquois shore line, 2 miles west of Dickersonville, New York. Lacustrine plain, bed of lake Iroquois, near Jeddo, New York The water edge was at base of cliff. The cliff is carved from Medina shale (No. 1749).

754. Till plain, ½ mile south of Jeddo, Niagara county, New York (No. 1750).

755. Cross-bedding and unconformity in sand kame, 3 miles east of Lockport, New York (No. 1751).

756. Till. Shore of lake Ontario, Wilson, New York (No. 1752).

757. Deposit by torrent of Erian water on the withdrawal of the ice-sheet from the escarpment at Lewiston, New York. Unassorted and unworn alluvium (No. 1753).

758. Section of talus, Niagara gorge (No. 1754).

759. Angular gravel in kame, south of Royalton, Niagara county, New York (No. 1755).

760. Solitary gravel kame, 3 miles south of Middleport, New York (No. 1756).

761. Escarpment of the Niagara limestone; looking west from a point on the talus near Lewiston, New York (No. 1757).

762. Niagara escarpment capped by Niagara limestone; looking east from a point 5 miles west of Lockport, New York (No. 1758).

763. Niagara escarpment without capping of Niagara limestone; looking west from a point near Middleport, New York (No. 1759).
764. Drowned valley of Twelve-mile creek, near Wilson, Niagara county, New York. Water lilies grow on submerged alluvial plain (No. 1760).
765. Head of estuary of Twelve-mile creek, Niagara county, New York. Submerged alluvial plain supports rushes (No. 1761).
766. Estuary of Eighteen-mile creek, near Olcott, Niagara county, New York. Channel deep, current slow. Submerged alluvial plain supports rushes. (No. 1762).
767. Valley of Eighteen-mile creek, Niagara county, above head of estuary. Channel shallow, current rapid; alluvial plain dry except during flood (No. 1763).
768. Post-Glacial anticline, Hopkins creek, Niagara county, New York. The displacement of the rocks is accompanied by a superficial ridge traversing an alluvial terrace (No. 1764).
769. Section of Niagara limestone, Cooks quarry, near La Salle, Niagara county, New York. Shows structure described by James Hall, Geology of Fourth District of New York, pages 93 and 94 (No. 1765).
770. Section in cut of Erie railway, Niagara falls, New York. Shows structure described by James Hall, Geology of Fourth District of New York, pages 93 and 94 (No. 1766).
771. Weathering of Niagara limestone by solution. A joint face exposed in quarrying southwest of Middleport, New York (No. 1767).
772. Weathering of Niagara limestone by solution; old quarry southwest of Middleport (No. 1768).
773. Unconformity by erosion. Sandstones and shales of the Medina formation, Niagara gorge (No. 1769).
774. Isolated limestone mass at base of Niagara shale, containing "transition fauna" of Ringueberg (No. 1770).
775. Section of ripple-mark on Medina sandstone, Lockport, New York. From crest to crest, 23 feet; depth of trough, 29 inches (No. 1771).
776. Flagstone in court-house yard, Elyria, Ohio. Shows reticulated ripple-marks (No. 1772).
777. Trough of large ripple-mark in Medina sandstone, Niagara gorge, New York (No. 1773).
778. Crest of large ripple-mark in Medina sandstone. Quarry near Lewiston, New York (No. 1774).
779. Crest of large ripple-mark in Medina sandstone. Quarry in Lockport, New York (No. 1775).
780. Diverse cross-bedding associated with large ripple-marks in Medina sandstone. Quarry near Lewiston, New York (No. 1776).
781. Quarry face in Medina sandstone, Lockport, New York (No. 1777).
782. Quarry face in Niagara limestone, Lockport, New York. The joint face shows weather fracture (No. 1778).
783. Shore of lake Ontario at Wilson, New York. Train of shore drift from right, being arrested by bew-pin, begins to accumulate and partly protects bluff from wave attack. Dearth of shore drift under lee of pier favors wave attack; bluff eaten back 45 feet. Bluff contains two tills and cover of laminated clay, a deposit from lake Iroquois. Boulder pavement at top of lower till, indicated by arrow (No. 1779).

6 by 8 inches

784. Channel opened by Erian drainage while the ice-sheet occupied the Ontario basin, between Syracuse and Jamesville, New York. The channel is traversed by the Delaware, Lackawanna and Western railroad; looking west (No. 601).

785. Channel opened by Erian drainage while the ice-sheet occupied the Ontario basin. Two miles southwest of Jamesville, New York (No. 604).

786. Channel opened by Erian drainage while the ice-sheet occupied the Ontario basin. Three miles east of Marcellus village, New York; looking east. The upland through which the channel was eroded forms the skyline at the right (No. 630).

787. The Gulf. A channel opened by Erian drainage while the ice-sheet occupied the Ontario basin. Four miles west of Marcellus village; looking east (No. 646).

788. Channel opened by Erian drainage while the ice-sheet occupied the Ontario basin; three miles west of Palmyra, New York; looking west. The north wall, composed of drift, forms the skyline at the right. Boulders washed out of the drift appear in the foreground (No. 689).

789. Fractured anticline of post-Glacial formation in Helderberg limestone; Split rock, near Syracuse, New York; looking north (No. 623).

790. Fractured anticline of post-Glacial formation in Helderberg limestone; Split rock, near Syracuse; looking south (No. 624).

791. Watkins Glen, New York; a post-Glacial canyon in Devonian shale (negative lost).

792. Water-fall in Watkins glen; a post-Glacial canyon (No. 937).

793. Grouped joints in Devonian shale, Watkins glen (No. 938).

794. Drumlin 4 miles south of Newark, New York. Oblique view from the northeast (No. 684).

795. Side view of drumlins 5 miles south of Newark, New York; looking west-southwest. The direction of the ice motion was from right to left (No. 686).

796. Side view of drumlin about 2 miles southwest of Jamesville, New York. Ice motion from left to right (Nos. 606 and 607, panorama).

4 by 5 inches

797. Section of anticlinal ridge in railway cut one mile east of Dunkirk, New York. The rock is a black shale of Devonian age. The anticlinal structure was imposed after the retreat of the Pleistocene ice-sheet (No. 912).

798. Shore of Lake Ontario, at Pillar point, New York. Removal of glacial deposits by the waves has exposed a typical glaciated surface traversed by a few scratches ascribed to the grounding of icebergs. Published by T. C. Chamberlin, Seventh Annual Report U. S. Geol. Survey, page 166 (No. 915).

799. Shore of lake Ontario at Pillar point, New York. The aberrant scratches are ascribed to the grounding of icebergs. Same subject as No. 798 (No. 916).

Photographed for J. F. Kemp, Columbia University, New York

5 by 7 inches

800. Portage sandstone at Enfield gorge, near Ithaca, New York.

Photographed by H. L. Fairchild, Rochester, New York

6½ by 8½ inches

801. Lower Clinton limestone, with iron ore, ravine of the Genesee.

Photographed by W. H. Pynchon, Hartford, Connecticut

4 by 5 inches

802. Old shoreline of lake Ontario, near Rose village, New York, about 3 miles south of Sodus bay (No. 11).
803. Contact of Calciferous on fundamental gneiss; Little falls of the Mohawk, New York. The locality is on a cut of the West Shore railroad. Close upon the gneiss is a thin layer of conglomerate, considered to belong to the Calciferous (No. 9).
804. High falls of Genesee river at Rochester, New York. The lower fall (in the foreground) is determined by the Medina sandstone, the one next above by the limestone of the Clinton (No. 12).

Photographed by C. D. Walcott

6½ by 8½ inches. Negatives in United States Geological Survey

805. Middle quarry of the Penrhyn Slate Company, Middle Granville, Washington county, New York. Illustration of the bedding of the roofing slate. It is coincident with the line of cleavage (No. 97).
806. Same as 805; the light-colored stratum is a brecciated limestone conglomerate in a massive layer coincident with the cleavage of the roofing slate; northern and eastern sides of quarry (No. 99).
807. Same as 806 (No. 100).
808. Sandstone in Hudson shales, town of Argyle, Washington county, New York (No. 104).
809. Cliffs in Topmans gulf, Jefferson county, New York. Lorraine rocks; Utica shale with interbedded sandstone of the Lorraine series coming in above (No. 46).
810. Illustration of the decay of the upper semi-crystalline beds of the Trenton limestone at Rusts quarry, on east bank of West Canada creek, above Trenton Falls, New York (No. 113).
811. Cut in drift about one mile northwest of Gravesville, Herkimer county, New York (No. 118).
812. Distant view of "High falls," at Trenton Falls, New York (No. 112).
813. Boulder imbedded in crystalline Algonkian limestone, one mile north of Fort Ann, Washington county, New York, on roadside to Comstocks (No. 93).
814. Large boulder in crystalline Algonkian limestone, one mile north of Fort Ann, on roadside to Comstocks, Washington county, New York (No. 92).
815. Interior of Dixon plumbago mine, four miles west of Hague, Warren county, New York (No. 53).
816. Exterior view of Dixon plumbago mine, four miles west of Hague, Warren county, New York (No. 54).

Photographed by N. H. Darton

6½ by 8½ inches. Negatives in United States Geological Survey

Nos. 818–828, 830–834, 836, 838, 840–842, 845–850, 852–856 are published in Report of State Geologist of New York for 1893

817. Calciferous sandrock on East Canada creek, two miles above its mouth, Herkimer county, New York (No. 133).
818. Calciferous on East Canada creek, one mile above its mouth (No. 134).
819. Fault and dike in east bank of East Canada creek, a mile above its mouth (No. 131).
820. Fault and dike in east bank of East Canada creek, 1 mile above its mouth, looking east. On the left is Calciferous, with a breccia along the fault plane. In the center is the dike, which is a melilite-diabase. On the right are Trenton limestones below and shales and thin sandstones of the Utica formation above. The central opening is an adit made by prospectors (No. 132).
821. Ravine in Utica shales behind Canajoharie, New York (No. 143).
822. Gorge of Mohawk river, at Little Falls, New York. Calciferous in the foreground and to the left. Crystalline rocks along the river to the left and hills of Utica shale in the background. Looking west (No. 136).
823. The principal falls of Trenton Falls, New York, over Trenton limestone (No. 137).
824. Cascade in upper gorge at Trenton Falls, over Trenton limestone (No. 146).
825. Potsdam sandstone lying on crystalline rocks, just below Jessups landing, on Hudson river, Saratoga county, New York. Shows thin bedded sandstones and basal conglomerates and many points of actual contact with the crystalline rocks (No. 116).
826. Potsdam conglomerate on crystalline rocks near Mosherville, Saratoga county, New York (No. 118).
827. Glaciated surface of Potsdam conglomerate near Mosherville (No. 117).
828. Glens falls, on Hudson river. Looking west (No. 120).
829. Quarry in Trenton limestone, south bank of Hudson river, Glens Falls, New York (No. 121).
830. Calciferous on crystalline schists, West Shore railroad cut one mile west of Downing station, New York. Looking south (No. 128).
831. Lower portion of gorge at Trenton Falls, New York (No. 141).
832. Spencer falls, Trenton Falls, New York, over Trenton limestone (No. 140).
833. Quarry at Howes cave, Schoharie county, New York. Pentamerus and tentaculite beds of the Helderberg limestone (No. 148).
834. Pentamerus and tentaculite beds of Helderberg limestone at Indian Ladder, Albany county, New York (No. 157).
835. The Helderberg escarpment at Indian Ladder, Albany county, New York. Slopes of Hudson shale, cliffs of tentaculite, and pentamerus limestones; looking south (No. 154).
836. Part of panorama to the westward of 835, showing the "gulf" at Indian Ladder (No. 155).

837. The Helderberg escarpment south of Indian Ladder, Albany county, New York; looking southwest. Slopes of Hudson shale in the foreground. High cliffs of pentamerus beds of the Helderberg, surmounted by terraces of overlying limestones. Hills of Hamilton group in the background to the right (No. 156).
838. Quarry in Helderberg limestones just south of South Bethlehem, Albany county, New York. Exhibits tentaculite and pentamerus beds, used for road metal; looking south (No. 158).
839. Road metal quarry in pentamerus and tentaculite beds of Helderberg limestones at South Bethlehem (No. 159).
840. Creek falling into limestone cave (pentamerus beds of Helderberg limestone), west of Coxsackie, New York (No. 161).
841. Overturn and fault of Sprayt creek, one mile west of South Bethlehem, Albany county, New York. To the left are the Hudson shales, exhibiting an overturned anticlinal with nearly horizontal axis. They are overlain by thin-bedded Helderberg limestones, and at the top are heavier bedded limestones, which are overthrust along a fault plane which is seen in the middle of the right-hand side of the photograph (No. 162).
842. Anticlinal in Esopus shales (Cauda galli), Catskill creek, near Leeds, Green county, New York (No. 168).
843. Northern front of Catskills, and Cairo knob, from near Leeds. Catskill creek in the fore and middle ground (No. 186).
844. Wittemburg range, southern Catskills, from half a mile east of Shokan station; looking west (No. 185).
845. Esopus shales, on west bank of Esopus creek, two miles above Saugerties, New York. Ledges of Oriskany sandstone are seen along the east bank (No. 167).
846. Champlain clay lying against Helderberg limestones, west shore of Hudson river, near Rondout, New York; looking north (No. 169).
847. Quarry in Becraft limestone, Rondout, New York; looking north (No. 175).
848. Cement beds and limestones on Wallkill Valley railroad, one mile south of Whiteport, New York (No. 177).
849. Arch in Salina and Clinton beds at High Falls, Ulster county, New York; looking north (No. 182).
850. High Falls, Ulster county, New York. Over cement beds of the Salina formation; looking north (No. 180).
851. Clinton and Salina formations in west bank of Rondout creek at High Falls, Ulster county, New York (No. 181).
852. Looking southward across lake Mohonk, Ulster county, New York. This lake is surrounded by cliffs of Shawangunk grit. Published in National Geographic Magazine, volume vi, plate 2 (No. 190).
853. Eastern face of Shawangunk mountain, two miles south of lake Mohonk, Ulster county, New York. Shawangunk grit lying on Hudson shales. Published in National Geographic Magazine, volume vi, plate 3 (No. 196).
854. Cliffs of Shawangunk grit on west shore of lake Mohonk, Ulster county, New York (No. 189).
855. Awosting falls, on the Peterkill, near lake Minnewaska, Ulster county, New York. Over Shawangunk grit (No. 192).
856. Honk falls, over flaggy beds of Devonian age, near Napanoch, Ulster county, New York; looking north (No. 188).

Photographed by J. P. Bishop, 109 Norwood Avenue, Buffalo, New York

5 by 8 inches

857. Setting-tank for brine, Kerr salt works, Rock Glen, New York.
858. Works of Warsaw Salt Company, Warsaw, New York.
859. Salt pan, Genesee salt works, Biffard, New York.
860. Kettles with steam jacket, Standard works, Warsaw, New York.
861. Grainer process, Perry salt works, Perry, New York.
862. Barreling salt, Castile, New York.
863. Breaker, Retsof salt mine, Griegsville, New York.
864. Interior of same showing kettles.
865. Solar salt works, Syracuse, New York.
866. Draining salt, Solar salt works, Syracuse, New York.
867. Carting salt, Solar salt works, Syracuse, New York.

Photographed by J. F. Kemp, Columbia University, New York, New York

5 by 7 inches

868. The Adirondacks, looking eastward from the summit of mount Marcy

Photographed by S. R. Stoddard, Glens Falls, New York

6 by 8 inches. 35 cents each

869. Ausable chasm; grand flume, from rapids down (No. 19).
870. Ausable chasm; view upward from Table rock (No. 17).
871. Ausable chasm; Rainbow falls (No. —).
872. Ausable chasm; column rocks (No. 13).
873. Lake George; panorama from Pearl point to Black mountain (No. 804).
874. Lower Ausable lake, Adirondacks (No. 486).
875. Lake Placid and Mirror lake; from Grand View house (No. 79).
876. Indian pass, Adirondacks (No. 436).
877. Lake Champlain; looking northeastward from Westport (No. 556).
878. The palisades of lake Champlain (No. 560).
879. Upper Ausable lake; "The Gothics" (No. 488).
880. Upper Ausable lake; Haystack mountain (No. 489).
881. Clear lake, from mount Jo, Adirondacks (No. 66).
882. Howes cave, New York; "The Eagles Wing" (No. 515).
883. Howes cave, New York; "Alabaster Hall" (No. 521).
884. West Point; looking northward from plain (No. 131).
885. Glens Falls, Hudson river (No. 543).
886. Lower falls, Falls Creek gorge, Ithaca, New York (No. —).

5 by 8 inches. 30 cents each

887. The trail of the charcoal-burner, Adirondacks (No. 494).
888. Ray Brook, Adirondacks (No. 75).
889. Ausable chasm, Adirondacks (No. 404).
890. Upper Ausable lake, from Boreas bay (No. 34).
891. View from Saint Regis mountain, Adirondacks (No. 72).
892. Bog River falls, Adirondacks (No. 559).
893. Trap dike, Avalanche lake (No. 1057).

894. Avalanche lake, Adirondacks (No. 1055).
895. Hudson river, looking northward from West Point (No. 1311).
896. Hudson river, looking southward past Poughkeepsie (No. 1315).
897. Hudson river, looking northward from Fort Putnam (No. 1307).

Photographed by E. L. Edgerly, New York, New York

4 by 5 inches

898. Drift boulder, Bronx park, New York city.
899. Drift boulder, Bronx park, New York city.
900. Drift boulder, Bronx park, New York city.
901. Glaciated surface, Bronx park, New York city.

Photographed by J. F. Kemp, Columbia University, New York, New York

5 by 7 inches

902. Glacial furrows, Bronx park, New York city. The furrows are not far from the rocking stone, but they have no connection with it. They strike in a northwesterly direction across the foliation of the gneisses.
903. Rocking stone in Bronx park, New York city. By timing the effort to the period of the stone a man can make the top of the stone describe an arc of about 3 inches.

Photographed by E. L. Ferguson

6½ by 8½ inches

904. Perched rock in Westchester county, New York, near Mount Kisco.

Photographed by J. F. Kemp, Columbia University, New York

5 by 7 inches.

905. Boulder clay, new site of Columbia University, New York.

Photographed by J. K. Hillers

11 by 14 inches. Negatives in United States Geological Survey

906. The rapids above Niagara falls, seen from the Canadian side (No. 71).
907. The rapids and Canadian falls of Niagara, seen from Goat island (No. 68).
908. Niagara falls, from the American side (No. 73).
909. The American portion of Niagara falls, from Goat island (No. 74).
910. The American portion of Niagara falls, from the Canadian side (No. 75).
911. The American portion of Niagara falls, from the Canadian side (No. 63).

North Carolina

Photographed by I. C. Russell

8 by 10 inches. Negatives in United States Geological Survey

912. Fault in sandstone and shale of the Newark system, Bogan cut, near Wadesborough, North Carolina. Hade toward the west (No. 173).
913. Decomposed trap rock in Newark system at Wadesborough (No. 176).

Photographed by Arthur Keith

6½ by 8½ inches. Negatives in United States Geological Survey

914. Grandfather mountain and Watauga valley; looking west from the Blue ridge, North Carolina (No. 51).
915. West end of Grandfather mountain, showing above Blue ridge, North Carolina (No. 52).
916. South side of Grandfather mountain, from Yonahlossee road (No. 53).
917. Dissected plateau of Blue ridge at head of New river, North Carolina (No. 58).
918. Blue ridge and Blowing rock; looking east across the head of Johns river, North Carolina (No. 56).

Photographed by J. K. Hillers

11 by 14 inches. Negatives in United States Geological Survey

919. Looking north toward Asheville from High Point, North Carolina (No. 292).
920. View of the French Broad, North Carolina (No. 259).
921. View on the French Broad (No. 258).
922. View on the French Broad (No. 256).
923. View on the French Broad (No. 260).
924. View on the French Broad (No. 255).
925. View on the French Broad (No. 261).
926. Hickory Nut gap, North Carolina (No. 278).
927. Hickory Nut gap (No. 277).
928. Hotel in Hickory Nut gap (No. 276).
929. Hickory Nut gap (No. 281).
930. Hickory Nut gap (No. 279).
931. Cranberry iron works, North Carolina (No. 265).
932. Cranberry iron mines (No. 271).
933. Cranberry iron works (No. 266).
934. From the top of Blue Ridge gap, North Carolina, looking west (No. 282).

OREGON

Photographed by G. K. Gilbert

5 by 7 inches. Negatives in United States Geological Survey

935. Dunes, Biggs, Oregon (No. 506).
936. Dunes, Biggs (No. 509).
937. Dunes, Biggs (No. 507).
938. Wind-made ripples on dune, Biggs (No. 514).
939. Wind-made ripples on dune, Biggs (No. 513).
940. Spheroidal structure in volcanic rock. One mile east of Cascade locks, Oregon (No. 527).

Photographed by J. S. Diller

5 by 7 inches. Negatives in United States Geological Survey

941. The cable and house of the light-house keeper at mouth of Coos bay (no negative).

942. Rose's black sand mine. The bedrock in the foreground of Eocene shales and highly tilted. Upon this rests the black sand, which is overlaid by a considerable thickness of sands and clays (No. 364).

PENNSYLVANIA (INCLUDING NORTHERN DELAWARE)

Photographed by E. B. Harden for the Geological Survey of Pennsylvania

Negatives in photograph gallery of United States Geological Survey. They bear Harden's negative numbers, by which they should be ordered

943. Gilmore's slide tipple. Report K 4, Second Geological Survey of Pennsylvania, plate iii (No. 1586).
944. Caledonia tipple. Report K 4, Second Geological Survey of Pennsylvania, plate i (No. 1588).
945. Venetia Mine tipple, Peters creek. Report K 4, Second Geological Survey of Pennsylvania, plate xi (No. 1590).
946. Little Saw-mill Run Railroad Company's tipple, South Pittsburg. Report K 4, Second Geological Survey of Pennsylvania, plate x (No. 1591).
947. Amity Mine tipple. Report K 4, Second Geological Survey of Pennsylvania, plate ix (No. 1592).
948. Relief map of the rocky ridge and east broad top coal basins, in Huntington county, Pennsylvania. By Edward B. Harden (No. 1596).
949. Relief map of Bald Eagle mountain and Nittany valley. By Edward B. Harden (No. 1597).
950. Model of the Cornwall iron ore mines, looking north. Annual Report of Geological Survey of Pennsylvania, 1885 (No. 1598).
951. Compressed air locomotive, Old Eagle mine. Report K 4, Second Geological Survey of Pennsylvania, plate v (No. 1599).
952. Deshong's quarry, near Chester, Pennsylvania (No. 1601).
953. Ward's quarry, near Chester, Pennsylvania (No. 1602).
954. Ohlinger Dam quarry, showing both dip and cleavage in Laurentian gneiss, 3 miles northeast of Reading, Pennsylvania. Report D 3, volume 2, Second Geological Survey of Pennsylvania (No. 1604).
955. Leiper quarry, Delaware county, Pennsylvania (No. 1605).
956. Leiper quarry, Delaware county, Pennsylvania (No. 1607).
957. Old Quarry No. 2, at Slatington, Lehigh county, Pennsylvania, looking west. Report D 3, volume 1, Second Geological Survey of Pennsylvania, 1882, plate 1 (No. 1609).
958. American slate quarry No. 1, Slatington, Pennsylvania, looking southwest. Report D 3, volume 1, Second Geological Survey of Pennsylvania, 1883, plate 2 (No. 1610).
959. Trap on the south side of the Cornwall big hill, where the spiral railroad enters the upper workings. Annual Report of Geological Survey of Pennsylvania, 1885 (No. 1612).
960. Feldspar quarry, Brandywine Summit kaolin works, Delaware county; looking northeast, plate xxiii (No. 1613).
961. American kaolin works, New Garden township, Chester county; looking north. Report C 5, Second Geological Survey of Pennsylvania, plate, xxvii (No. 1614).

962. Kaolin mine at Hockessin, Delaware; looking northeast. Report C 5, Second Geological Survey of Pennsylvania, plate xxviii (No. 1615).
963. Potsdam sandstone of Neversink hills, exposed in the railway cut at the Lover's Leap, 3 miles south of Reading, Berks county, Pennsylvania; looking southeast. Report D 3, volume 2, Second Geological Survey of Pennsylvania (No. 1617).
964. Contorted gneiss; Schuylkill river, $\frac{3}{4}$ mile above Lafayette station, Schuylkill Valley railroad. No. 158 (No. 1618).
965. Cut on Schuylkill Valley railroad, showing "creep" (No. 1619).
966. Kettle-holes in the moraine in Cherry valley, Monroe county, Pennsylvania; looking north-northeast. Report Z, Second Geological Survey of Pennsylvania, plate vii (No. 1620).
967. The terminal moraine crossing Cherry valley, Monroe county, Pennsylvania; looking southwest. Report Z, Second Geological Survey of Pennsylvania, plate viii (No. 1621).
968. Long ridge; the terminal moraine on the Pocono plateau, 2,000 feet above tide; Monroe county; looking north-northeast. Report Z, Second Geological Survey of Pennsylvania, plate ix (No. 1622).
969. Moraine kettle and kames in Cherry valley, Monroe county, Pennsylvania. Report Z, Second Geological Survey of Pennsylvania, plate x (No. 1623).
970. Kames in Cherry valley, Monroe county, Pennsylvania. Report Z, Second Geological Survey of Pennsylvania, plate xi (No. 1624).
971. Glacial scratches on Clinton red shale (No. 5), near Fox gap, Monroe county, Pennsylvania, plate xii (No. 1625).
972. Great glacial grove on table rock, at the Delaware water gap. Report Z, Second Geological Survey of Pennsylvania, plate xv (No. 1626).
973. The terminal moraine west of Coles creek, in Columbia county. Report Z, Second Geological Survey of Pennsylvania, plate xviii (No. 1627).
974. Glacial till exposed at the Bangor slate quarry at Bangor, Northampton county. Report Z, Second Geological Survey of Pennsylvania, plate iv (No. 1628).
975. A glaciated boulder at the Bangor slate quarry, at Bangor, in Northampton county, Pennsylvania. Report Z, Second Geological Survey of Pennsylvania, plate v (No. 1629).
976. Terminal moraine near Saylorsburg, Monroe county, Pennsylvania; looking north-northwest. Report Z, Second Geological Survey of Pennsylvania, plate vi (No. 1630).
977. Boulder of Pottsville conglomerate on the crest of Penobscot mountain, Luzerne county, Pennsylvania; looking west. Report Z, Second Geological Survey of Pennsylvania, plate xvi (No. 1631).
978. The Bryn Mawr gravel at Crawford's fireclay pit, Delaware county, looking north 34 degrees west. Report C 5, Second Geological Survey of Pennsylvania, plate xxii (No. 1633).
979. Glacial striæ on the southern slope of Godfrey's ridge, in Monroe county, Pennsylvania. Report Z, Second Geological Survey of Pennsylvania, plate xiii (No. 1634).
980. Front side of terminal moraine near Bangor, Northampton county, looking southeast. Report Z, Second Geological Survey of Pennsylvania, plate i (No. 1635).

981. Inside view of terminal moraine near Bangor, Northampton county, looking northwest. Report Z, Second Geological Survey of Pennsylvania, plate 2 (No. 1636).
982. Moraine hummocks west of Bangor, Northampton county, looking southwest. Report Z, Second Geological Survey of Pennsylvania, plate 3 (No. 1637).
983. Castle rock, Edgemont township, Delaware county, Pennsylvania (No. 1640).
984. Lafayette soapstone quarry, Montgomery county, Pennsylvania (No. 1649).
985. Trap boulders, French Creek falls, Pennsylvania (No. 1652).
986. Trap boulders, French Creek falls, Pennsylvania (No. 1653).
987. Trap boulders, French Creek falls, Pennsylvania (No. 1654).
988. Water Sheet narrows, Huntingdon county, Pennsylvania. Juniata river (No. 1655).
989. Breaker at Hollywood colliery, showing stripping (No. 1656).
990. Synclinal in mammoth bed, Hollywood colliery, Hazelton, Pennsylvania. Shows open-work mining after stripping (No. 1657).
991. Gneiss peak on Harvey Thomas farm, L. Bethel township, Delaware county, Pennsylvania (No. 1661).
992. Burned rocks, Fayette city, Monongahela river (No. 1662).
993. Rausch's gravel quarry, Bethlehem, Pennsylvania (No. 1663).
994. Limestone quarry, Bethlehem, Pennsylvania (No. 1664).
995. Old Wheatley lead mine, near Phœnixville, Pennsylvania (No. 1665).
996. Old Smelting Works mine, near Phœnixville, Pennsylvania (No. 1666).
997. Old Wheatley lead mine, near Phœnixville, Pennsylvania (No. 1667).
998. Head frame, Kaska William colliery, Schuylkill county, Pennsylvunia (No. 1669).
999. Delaware water gap (No. 1680).
1000. Avondale quarry, Delaware county, Pennsylvania (No. 1681).
1001. Contorted gneiss, Spring Mill, Montgomery county (No. 1683).
1002. Contorted gneiss, Spring Mill, Montgomery county (No. 1684).
1003. Anticlinal on Schuylkill river 2 miles above Port Clinton (No. 1685).
1004. Cut on Schuylkill Valley railroad showing "creep" (No. 1686).
1005. Potts' limestone quarry, below Norristown (No. 1687).
1006. Limestone quarry, Port Kennedy, Phœnix Iron Company (No. 1693).
1007. Limestone in Schuylkill Valley railroad cut near Mogeetown, Pennsylvania (No. 1697).
1008. Contorted gneiss of Wissahickon creek, near the Philadelphia and Reading railroad bridge. Report C 4, plate viii, Geological Survey of Pennsylvania (No. 1699).
1009. Creep striæ on roofing slate, Bangor, Northampton county, Pennsylvania. Report Z, plate 61, Geological Survey of Pennsylvania (No. 1700).
1010. Creep striæ on roofing slate, Bangor, Northampton county, Pennsylvania. Report Z, plate 61, Geological Survey of Pennsylvania (No. 1701).
1011. Glaciated boulder from moraine, base of Huntingdon mountain, near Jonestown, Columbia county, Pennsylvania. Report Z, plate 118, Geological Survey of Pennsylvania (No. 1702).
1012. Stripping at Hollywood colliery No. 1, looking east. Report A. C., Second Geological Survey of Pennsylvania, page plate No. 52 (No. 1574).
1013. Workings at Hollywood colliery No. 1, looking south. Report A. C., Second Geological Survey of Pennsylvania, page plate No. 53 (1579).

1014. Pottsville deep shaft. Report A. C., Second Geological Survey of Pennsylvania, page plate No. 33 (No. 1580).
1015. Kohinoor Colliery culm and rock dump. Report A. C., Second Geological Survey of Pennsylvania, page plate No. 50 (No. 1583).
1016. Anderson's tipple, Venetia, N. W. (No. 1584).
1017. Black Diamond tipple. Report K 4, Second Geological Survey of Pennsylvania, plate iv (No. 1585).
1018. Snow Hill tipple. Report K 4, Second Geological Survey of Pennsylvania, plate ii (No. 1587).
1019. New Coal Bluff tipple. Report K 4, Second Geological Survey of Pennsylvania (No. 1595).
1020. Breaker in process of construction, Kohinoor colliery. Report A. C., Second Geological Survey of Pennsylvania, page plate No. 45 (No. 1581).
1021. Boring for oil. Sadsbury township, Chester county, Pennsylvania (No. 1659).
1022. The terminal moraine crossing Fishing Creek valley, Columbia county, Pennsylvania; looking southwest. Report Z, Second Geological Survey of Pennsylvania, plate xvii (No. 1632).
1023. Culm and rock heaps at Shenandoah. Report A. C., Second Geological Survey of Pennsylvania, page plate No. 49 (No. 1582).
1024. Stripping at Hollywood Colliery No. 1; looking east. Report A. C., Second Geological Survey of Pennsylvania, plate No. 51 (No. 1577).
1025. Workings at Hollywood colliery; looking east. Report A. C., Second Geological Survey of Pennsylvania, plate No. 12 (No. 1578).
1026. Avondale quarry, Delaware county, Pennsylvania (No. 1600).
1027. Ward's quarry, near Chester, Pennsylvania (No. 1603) (duplicate of No. 953).

Photographed by G. P. Merrill, United States National Museum

1028. Fold in slate quarry, Bangor, Pennsylvania.
1029. The Franklin slate quarry, Slatington, Pennsylvania.
1030. Slate quarry, Bangor, Pennsylvania.

Photographed by C. D. Walcott

6½ by 8½ inches. Negatives in United States Geological Survey

1031. Shales, broken down by superincumbent weight, or creeping; half a mile north of Columbia, Lancaster county, Pennsylvania; beside Pennsylvania railroad tracks (No. 188*c*).
1032. Different view of 1031 (No. 188*b*).
1033. Cliff of massive bedded Lower Cambrian limestone, bluish black at the base, white above and capped by thinner layers of a dark arenaceous limestone. Quarries on the line of the Pennsylvania railroad at Bellemont, Lancaster county, Pennsylvania (No. 196*a*).
1034. A closer view of the cliff. Quarries at Bellemont post-office, Lancaster county, Pennsylvania, on the line of the Pennsylvania railroad (No. 198*b*).
1035. Quarry near Bellemont post-office, Lancaster county, Pennsylvania. This quarry shows the brecciation, caused by jointing and cleavage planes, of the massive limestone shown in 1033 (199*a*).

1036. Lower Cambrian limestone, exposed in quarries at Bellemont, Lancaster county, Pennsylvania, on line of Pennsylvania railroad, a little east of 881. The massive limestones of 1033 are here capped by a band of conglomerate limestone which rests on the thin bedded limestone shown in the top of quarry (No. 197*b*).
1037. Banded Lower Cambrian rocks, just southwest of Emigsville, York county, Pennsylvania (No. 184).
1038. Synclinal fold in Lower Cambrian limestone. Limestone quarry of the east side of York, Pennsylvania, within the city limits (No. 192).
1039. Portion of massive layer of conglomerate limestone. Quarry quarter of a mile north of Stoners station, York and Wrightsville railroad, York county, Pennsylvania (No. 181*a*).

Photographed for N. H. Darton

6½ by 8½ inches. Negatives in United States Geological Survey

1040. Typical field of gabbro boulders, southeastern Pennsylvania (No. 233).

Photographed by T. C. Hopkins, Syracuse, New York

3½ by 4½ inches

1041. View on the Ohio River bluff opposite Beaver, showing concentric weathering in shale. The weathering from the joints shows concentric peeling off on a large scale, with smaller concretionary masses inside.

Photographed by W. C. Stevenson

3½ by 4½ inches

1042. Cambrian limestone, Earnest station, Pennsylvania railroad, near Morriston, Pennsylvania.
1043. Potsdam sandstone exposure, Rhodes quarry, Edge Hill, Montgomery county, Pennsylvania.
1044. Potsdam sandstone, Smith's quarry, Edge Hill.

South Carolina

Photographed under direction of J. K. Hillers

11 by 14 inches. Negatives in United States Geological Survey

Published in part in the Ninth Annual Report of the United States Geological Survey.

1045. Worst wreck in Charleston, East Bay street, near Chalmers; looking south (No. 18).
1046. Displaced coping and portico of old guard-house, southwest corner of Meeting and Broad streets, looking southwest, Charleston, plate xv (No. 16).
1047. Displaced gable, southeast corner of Queen and Mazyck streets, looking south-southeast, Charleston (No. 5).

1048. Displaced towers and coping of City hospital, southwest corner of Logan and Magazine streets, looking west, Charleston (No. 20).
1049. The same, looking west-southwest, Charleston, plate xviii (No. 21).
1050. Saint Philips church, Church street between Queen and Cumberland streets, looking north, Charleston, plate xvi (No. 2).
1051. Displaced chimney, southwest corner of Beaufin and Archdale streets, looking east-northeast, Charleston (No. 19).
1052. Thrown gable and twisted chimney, residence of late Bishop Lynch, Broad street opposite Orange, looking northeast, Charleston (No. 6).
1053. Thrown portico, Hibernian hall, Meeting street opposite Chalmers, looking north-northwest, Charleston (no negative).
1054. Fissure in front of 167 Tradd street, between Council and Rutledge, looking east-southeast, Charleston (No. 15).
1055. Characteristic wreck, 167 Tradd street, between Council and Rutledge, looking southeast, Charleston (No. 3).
1056. Displaced portico, Synagogue, Hasel street between King and Meeting, looking north-northwest, Charleston (No. 8).
1057. Thrown house, looking south, Lincolnville (No. 4).
1058. Displaced monument, First Presbyterian Church, southwest corner of Meeting and Tradd streets, looking east, Charleston (No. 26).
1059. Displaced monument, Saint John's Lutheran church, Archdale street between Clifford and King, looking north, Charleston (No. 32).
1060. Derailed locomotive, looking west, Ten-mile hill, plate xix (No. 9).
1061. Sink, Ten-mile hill (No. 13).
1062. Craterlet, Ten-mile hill, plate xxi; 203, plate xx (No. 11).
1063. Craterlet, Ten-mile hill, plate xxi (No. 12).
1064. Craterlet, Ten-mile hill, plate xx (No. 10).
1065. Craterlet, Ten-mile hill (No. 14).

SOUTH DAKOTA

Photographed by N. H. Darton

6½ by 8½ inches. Negatives in United States Geological Survey

1066. Titanotherium beds, edge of Big Bad lands of South Dakota, Corral draw, Washington county, South Dakota (No. 264).
1067. Titanotherium beds on Pierre shale, southeast side of Indian draw; shows bed of water-bearing gravel; Washington county (No. 371).
1068. Big Bad lands; Protoceras sandstones on Oreodon clays, head of Indian draw; looking northwest; Washington county (No. 374).
1069. Big Bad lands; Protoceras sandstone area; looking southeast into head of Cottonwood draw; Washington county (No. 375).
1070. Big Bad lands; looking southeast into Cottonwood draw from head of Indian draw; from divide on Protoceras sandstone; Washington county (No. 376).
1071. Big Bag lands; spur of south end of Sheep mountain; volcanic ash beds near top; Washington county (No. 378).
1072. Big Bad lands; south end of Sheep mountain and Devils tower; volcanic ash bed near top; looking northeast; Washington county (379).

1073. Big Bad lands; south end of Sheep mountain from the southeast; volcanic ash bed near top; Washington county (No. 380).
1074. Protoceras sandstone on Oreodon beds 2 miles east of mouth of Wounded Knee creek; looking east; Washington county (No. 385).
1075. Protoceras sandstone area, Big Bad lands (No. 519).
1076. Protoceras sandstone area, Big Bad lands (No. 520).
1077. Protoceras sandstone area, Big Bad lands (No. 522).
1078. Protoceras sandstone area, Big Bad lands (No. 523).
1079. Protoceras sandstone area, Big Bad lands (No. 524).
1080. Natural bridge, Protoceras sandstone area, Big Bad lands (No. 526).
1081. Protoceras sandstone area, Big Bad lands (No. 531).
1082. Big Bad lands of South Dakota, in the vicinity of the Flour trail; looking north (No. 506).
1083. Looking west over portion of Big Bad lands near Flour trail (No. 507).
1084. Looking west over portion of Big Bad lands from near Flour trail (No. 509).
1085. Looking southwest over a portion of Big Bad lands near Flour trail (No. 510).
1086. Sandstone lenses near Flour trail, Big Bad lands (No. 515).
1087. Columns of clay capped by sandstone near Flour trail, Big Bad lands (No. 517).
1088. Looking down head of South fork of Coral draw, Big Bad lands (No. 532).
1089. Big Bad lands in the vicinity of Flour trail, looking west (No. 536).

8 by 10 inches

1090. Big Bad lands of South Dakota, east side of Cedar draw, Washington county Columns capped by sandstone, White River formation (No. 637).
1091. Big Bad lands of South Dakota, head of Cedar draw. Erosion forms in Titanotherium sands (No. 643).
1092. Big Bad lands of South Dakota, east side of Cedar draw. Columns of sandy clay capped by sandstone (No. 648).
1093. Big Bad lands of South Dakota. A portion of the divide between Battle draw and Cedar draw. Oreodon beds of White River formation (No. 647).
1094. Big Bad lands of South Dakota, looking across head of Battle draw, Washington county. Titanotherium beds in middle-ground, overlain by Oreodon beds on the higher slopes. Late afternoon view (No. 642).
1095. Fossil tree in lower Cretaceous sandstone southwest of Minnekahta station, Southern Black hills (No. 673).
1096. Thermal spring at Cascade springs, Black hills (No. 672).
1097. Granite needles near Harney peak, Black hills (No. 618).
1098. Granite needles near Harney peak, Black hills, near view; Telephoto (No. 619).
1099. "Hogbacks" of Dakota sandstone on south side of Buffalo gap, Black hills, looking southwest (No. 622).
1100. Grindstone quarry in Dakota sandstone north of Edgemont, southern margin of Black hills uplift (No. 670).
1101. Sandstone dike, southeast of Maitland, in Benton shales (No. 754).
1102. Beecher rocks. Erosion in pegmatite, south of Custer (No. 746).
1103. Oligocene cross-bedded gravel in railroad cut south of Fairburn (No. 780).

6½ by 8½ inches

1104. Gypsum in red beds, Hot Springs, Black hills, South Dakota (No. 473).
1105. Jurassic sandstone on supposed Triassic red beds, 7 miles south of Hot Springs, Black hills, South Dakota (No. 474).
1106. Cone-in-cone concretion in Pierre shale, southeast of Hot Springs, South Dakota (No. 472).
1107. Granite needles near Harney peak, Black hills, South Dakota (No. 465).
1108. Granite needles near Harney peak, Black hills, South Dakota (southern group) (No. 468).
1109. Natural bridge in middle Jurassic sandstone near Buffalo gap, Black hills (No. 480).
1110. Faulted middle Jurassic sandstone near Buffalo gap, Black hills (No. 479).
1111. Cambrian sandstone on crystalline schists one mile north of Deadwood, South Dakota (No. 256).

Photographed by C. D. Walcott

5 by 7 inches. Negatives in United States Geological Survey

1112. View of pegmatite rocks on Sylvan lake 6 miles north-northeast of Custer, Black hills (No. 405).
1113. View of pegmatite rocks on Sylvan lake 6 miles north-northeast of Custer, Black hills (No. 406).
1114. View of pegmatite rocks on Sylvan lake 6 miles north-northeast of Custer, Black hills (No. 408).
1115. View from the summit of Harney peak, Black hills (No. 410).
1116. View from the summit of Harney peak, Black hills (No. 412).

Photographed by J. F. Kemp, Columbia University, New York, New York

7 by 7 inches

1117. Open cut in Father de Smet mine, Black hills of Dakota.
1118. Old Abe cut, Lead City, Black hills.
1119. Deadwood gulch, near Deadwood, Black hills. The near cliffs are phonolite.
1120. Bear butte from Plain to South Black hills, a trachyte plug.

Photographed by Gràbill Portrait Company, Chicago, Illinois

1121. "Spearfish falls," Black hills.
1122. "Needle point," Elk canyon, on Black Hills and Fort Pierre railroad.

Photographed by Iowa Geological Survey

6½ by 8½ inches

1123. Canyon in Sioux quartzite, new, taken from bottom, Dell rapids.
1124. Cross-bedding in Sioux quartzite, Sioux Falls.
1125. Palisades, showing Sioux quartzite on Split Rock creek, Minnehaha county
1126. Palisades as in 1125; distant view.

TENNESSEE

Photographed by J. K. Hillers

11 by 14 inches. Negatives in United States Geological Survey

1127. Marble quarry, Knoxville (No. 241).
1128. Doe River gorge (No. 250).
1129. Doe River gorge (No. 245).

Photographed by C. D. Walcott

6½ by 8½ inches. Negatives in United States Geological Survey

1130. Folds in Cambrian sandstone and shales; railroad cut about 1½ miles above Hampton, Tennessee, on Doe river (No. 137).
1131. Compressed anticlinal and fault plane in Nashville sandstone, near western end of Little river gap, Chilhowee mountain, Tennessee (No. 139).
1132. Cliff of Cambrian sandstone, northern side of Doe river gorge, about 2 miles above Hampton (No. 143).
1133. Cliff of Cambrian sandstones; southern side of Doe river gorge, about 2 miles above Hampton (No. 142).

Photographed by J. F. Kemp, Columbia University, New York, New York

5 by 7 inches

1134. The Mary copper mine, based on a great vein of copper-bearing pyrrhotite, at Ducktown, Tennessee. The vein outcrops in a marked peneplain of mica schists, which is surrounded by a rim of high hills.
1135. Iron ore mine based on the "gossan" of a pyrrhotite vein, Isabella mine, Ducktown, Tennessee.

TEXAS

Photographed by the Geological Survey of Texas, Austin, Texas

6½ by 8½ inches

1136. Kountz series; contact of volcanic ash and chalk.
1137. Kountz series; flints on hill.
1138. Pilot Knob series; view under bluff of great anticline; decomposition of tuff and stalagmites.
1139. Pilot Knob series; bored limestone above tufa.
1140. Mount Bonnell series; under the cliff.
1141. Mount Bonnell series; Colorado river from.
1142. Bee Spring series; fault in limestone.
1143. Barton Creek series; fault in limestone.
1144. Travis Peak series; Trinity beds.
1145. Shoal creek shell bank; Exogyra arietina, Roem.
1146. Flint nodules in chalk; southern bank of Colorado river.

UTAH

Photographed by C. D. Walcott

6½ by 8½ inches. Negatives in United States Geological Survey

1147. Summit of Carboniferous limestone. Hurricane cliff, about 10 miles south of Toquerville (no negative).
1148. Unconformity between Carboniferous and Permian. On Hurricane cliff, 10 miles south of Toquerville (No. 9).
1149. Looking toward the cliffs from south of Virginia City (No. 2).
1150. Permian cliff east of Toquerville (No. 6).

VERMONT

Photographed by J. F. Kemp, Columbia University, New York, New York

5 by 7 inches

1151. Red Cambrian quartzite, as exposed in the quarries at Willard's ledge, Burlington, Vermont.
1152. Trap dike in red Cambrian quartzites at the Willard's ledge quarries, Burlington.
1153. Overthrow of Cambrian sandstone on Utica slate, Lone Rock point, just north of Burlington. The water is lake Champlain.
1154. Cambrian sandstone overlying Utica slate, which is not visible in this view, having dipped out of sight. Lone Rock point, just north of Burlington.

Photographed by G. P. Merrill, United States National Museum

4 by 5 inches

1155. Marble quarry, West Rutland, Vermont.

Photographed by C. D. Walcott

6½ by 8½ inches. Negatives in United States Geological Survey

1156. Highgate falls, Vermont (No. 29).
1157. Brecciated limestone conglomerate. Calciferous zone, 1 mile south of Highgate falls (No. 43).
1158. Seams in limestone filled with calc-spar. Calciferous formation near Limekiln point, Highgate Springs, Vermont (No. 39).
1159. Seams in limestone filled with calc-spar. Calciferous formation near Limekiln point, Highgate Springs (No. 41).
1160. Contact of rocks of lower Cambrian and lower Ordovician age, on the line of the great fault, about 2½ miles northeast of Highgate Springs (No. 37).
1161. Plane of overthrust fault, north side of river, below Highgate falls (No. 31).
1162. Plicated slates, 1½ miles east of Wells post-office, Rutland county, Vermont (No. 74).
1163. Summit of an anticlinal fold, 4 miles west of West Arlington, Vermont (No. 73).
1164. Plane of overthrust fault, north side of river, below Highgate falls, Vermont (No. 30).

VIRGINIA AND WEST VIRGINIA

Photographed by J. Erbach

11 by 14 inches. Negatives in United States Geological Survey

1165. Outcrop of coal at Bingly slope, in the north end of the Black Heath basin. View along a recent slope; looking north 12 degrees west. Richmond coal field, Virginia.
1166. Irwin Bass place, western border, south of Mosley junction. Upper part of ravine in gneiss just west of border. Shows terraces and graded streams. Recent stream work.
1167. A dry swamp hole northwest of Skinquarter, Virginia, showing mud-cracks and grass border, after a protracted drought.
1168. Fragment of prismatic coke from Saunders slope, at Gayton, between 600 and 700 foot level, at contact with decomposed vertical trap dike. This is the popping coke.
1169. An outcrop of the columnar coke, north of Saunders slope, in valley of small stream. Slaty band at top.
1170. View of south bank of James river from Mr Parson's house, at Vinita, Virginia, flood-plain in foreground; looking south.
1171. James river and Cornwallis hill; looking west-northwest from Goat hill.

Dismal Swamp Series. Photographed by I. C. Russell

6½ by 8½ inches

Numbers 1172, 1173, 1174, 1175, 1180, 1182, 1184, and 1187 published by N. S. Shaler in the Tenth Annual Report of the United States Geological Survey.

1172. View showing the general aspect of the swamp in the district where the forest is relatively dense. In the foreground a single elevated root arch of the black gum is plainly shown; also a great number of cypress knees (No. 272).
1173. Southern margin of Dismal swamp, 12 miles west of Elizabeth City, North Carolina, showing the general aspect of the swamp in the month of May. The spur-like projections in the foreground are the knees belonging to the roots of the large cypress on the left hand. The gnarled excrescences at its base exhibit one type of root arches. In the center of the picture is a single root arch of the common type (No. 270).
1174. View showing general aspect of the wide, swampy channels which connect the main Dismal swamp with the tributary morasses lying to the west (No. 280).
1175. View of the swamp about a mile and a half east of Drummond lake, showing the ordinary condition of the wetter parts of the swamp in the growing season (No. 263).
1176. Southern margin of the swamp near Elizabeth City, North Carolina (No. 283).
1177. View near the southern border of the main swamp near Elizabeth City, North Carolina (No. 284).
1178. View of Jericho ditch (No. 273).
1179. Cypress trees in the eastern part of lake Drummond (No. 271).

1180. Cypress trees in the eastern part of lake Drummond (No. 275).
1181. View of the western shore of lake Drummond, showing the wall-like character of the forest growth (No. 278).
1182. View of Jericho ditch. The foliage on the right hand represents a canebrake. The trees on the left hand of the picture are of second growth (No. 277).
1183. View of Jericho ditch (No. 276).
1184. View showing thinly wooded portion of the main swamp area. The trees are mostly of second growth; the surface bears a scanty growth of cane (No. 282).
1185. View showing the general aspect of the wide, swampy channels connecting the main Dismal swamp with tributary morasses lying to the west of that area (No. 285).
1186. View of Jericho ditch (No. 279).
1187. Dismal Swamp canal; looking southward from the village of Wallaceton. The land on either side has been reclaimed from the original condition of swamp (No. 274).

Photographed by C. D. Walcott

6½ by 8½ inches. Negatives in United States Geological Survey

1188. Lace falls, Cedar creek; 1 mile above Natural bridge, Virginia (No. 136).
1189. Natural bridge, Virginia, from southeastern side (No. 119).
1190. Natural bridge, from northwestern side; looking through arch (No. 123).
1191. Natural bridge, from southeastern side (No. 121).
1192. Erosion of slaty banded limestone; bed of Cedar creek, about 1 mile below Natural bridge (No. 133).
1193. Plicated slaty limestone; same locality as 1192 (No. 129).
1194. Contorted slaty limestone; same locality as 1192. Massive limestone in foreground (No. 135).
1195. Folds in Cambrian shales; northern bank of Cedar creek; 1½ miles below Natural bridge (No. 130).

Photographed by C. H. James, 624 Arch Street, Philadelphia, Pennsylvania

Stereoscopic views of the Luray caverns of Virginia. Price, 25 cents each

1196. Side view in ball-room.
1197. Collin's grotto.
1198. Entrance to ball-room.
1199. Double column.
1200. Giant's hall.
1201. Lost blanket.
1202. Titania's veil from Hollow column.
1203. Empress column.
1204. Saracen's tent.
1205. Fallen column.
1206. Organ room.
1207. Skeleton gorge.

Photographed by I. C. Russell

8 by 10 inches. Negatives in United States Geological Survey

1208. Fields of residual clay near Natural bridge, Virginia. Published in Bulletin 52, United States Geological Survey (No. 39).

Photographed by H. R. Geiger

8 by 10 inches. Negatives in United States Geological Survey

1209. Arched strata on Chesapeake and Ohio canal, probably near Hancock, West Virginia (No. 177).
1210. Fold in brown sandstone on Chesapeake and Ohio canal, 2 miles above Hancock, West Virginia (No. 175).

Photographed by N. H. Darton

6½ by 8½ inches. Negatives in United States Geological Survey

1211. Anticline in Lewistown limestone, South branch of Potomac river near Hopeville, West Virginia (No. 222).
1212. Anticline and thrust fault in Tuscarora quartzite, Panther gap, Virginia; looking south (No. 245).
1213. Anticline of Tuscarora quartzite, Panther gap; looking south (No. 251).

Photographed by J. F. Kemp, Columbia University, New York, New York

5 by 7 inches

1214. Arch of Upper Silurian quartzite forming the "Rainbow," at Iron gate, near Clifton forge, Virginia. The arch is exposed in the valley of the James river. Another stratum of quartzite forms a parallel arch higher up, which does not appear, from lack of distance in taking the view.
1215. Overthrown fold of Upper Silurian quartzite in Eagle mountain, in the valley of the James river, Virginia.
1216. One limb of fold of Upper Silurian quartzite forming Rathole mountain, just across the James river from number 1215.

WASHINGTON

Photographed by B. Willis

6½ by 8½ inches. Negatives in United States Geological Survey

1217. Stehekin valley, about 2 miles east of Cascade pass, Cascade range, Washington; showing the profile due to profound erosion followed by glaciation (No. 196).
1218. Cascade pass, Cascade range. Basin at the head of Stehekin east of the pass, showing the character of the glacial amphitheaters and the remnants of glaciers (No. 199).
1219. Cascade pass, Cascade range. View from the summit of the pass, 5,300 feet, southward to the headwaters of Cascade river. The high peaks rise to about 8,800 feet (No. 200).

1220. Cascade pass, Cascade range. Cliffs of hornblendic gneiss immediately south of the pass, about 3,000 feet in height, exhibiting vertical jointing (No. 201).

1221. Cascade pass, Cascade range. Glacier and basin at the head of Stehekin river (No. 202).

1222. Basin peak, Cascade range, north of Cascade pass. View of doubtful lake and slope of the mountain, showing joint systems, which are commonly mineralized (No. 204).

1223. Cascade pass, Cascade range. Typical glacier of the northern Cascade range, showing a névé and the incipient ice-stream, with crevasses (No. 207).

1224. Detail of number 1123, showing stratification of the ice and structure of the glacier. Taken from the same point as number 1123 with long-focus lens (No. 208).

1225. Cascade pass, Cascade range. View from an elevation of about 7,500 feet southeastward down the Stehekin valley. The mountain summits fall into a general plane, which was a lowland of late Pliocene time and is now elevated 8,000 feet above sea and profoundly dissected (No. 210).

1226. Cascade pass, Cascade range. A typical glacier of the high Cascades, showing the character of crevassing and terminal moraines (No. 212).

1227. Navarre coulee, lake Chelan, Washington. Torrent wash due to cloudburst on granite slopes in arid climate (No. 167).

1228. Columbia valley, Washington, southeast of lake Chelan; looking northeast across the river to the terraces of Pleistocene age and the high plateau of Miocene basalt (No. 163).

1229. Columbia river, east of lake Chelan. View down the valley from terrace to 3 miles north of outlet of the lake. Terracing on the east bank of the river is due to the occupation of the valley by a lobe of the Okanagan glacier (No. 221).

1230. Gravel terraces of stream origin in the delta of Chelan river, at its junction with the Columbia (No. 227).

1231. Columbia river, east of lake Chelan, showing sand dunes resulting from floods and sediment of the Chelan river (No. 228).

1232. Chelan falls, Columbia river, looking south from near the outlet of lake Chelan. The valley and foreground were occupied by a lobe of the Okanagan glacier, which extended downstream to the even-topped terrace. The terrace is 600 feet above the Columbia, and represents a filling during the Glacial epoch which has subsequently been in large part removed (No. 231).

1233. Delta of Chelan river, at its junction with the Columbia (No. 223).

1234. Lake Chelan; looking down lake, showing Round mountain and hanging valley of Railroad creek (No. 216).

1235. Lake Chelan; looking south across the eastern end of the lake to Lakeside and Chelan butte. A glacial terrace and post-glacial ravine are conspicuous in the front of the butte (No. 218).

1236. Lake Chelan; exhibiting the canyonlike gorge which the lake occupies (No. 182).

1237. Lake Chelan; view northward across eastern end of lake, showing terraces produced during glacial occupation of the lake basin in lakelets between the ice and the land (No. 183).

1238. East end of lake Chelan. Detailed view of drift dam, showing cross-stratified sandy clays covered by till, gravel, wash, and turf in ascending succession. Between the till and the cross-stratified sands are pockets of coarse gravels and boulders, which probably correspond to stream channels (No. 193).

1239. Lake Chelan and outlet. General view of the drift dam and the site of Chelan (No. 194).

1240. Carbon River glacier, mount Rainier. View from the eastern lateral moraine of the Carbon River glacier, showing the sweep of the ice as it descends from beneath the great northern amphitheater of mount Rainier. In the foreground the slope of the lateral moraine toward the glacier shows how extensively it has lost in volume, and the ice is covered with morainal material (No. 16).

1241. Flora east of Carbon River glacier, mount Rainier. August flora on the edge of the Carbon River glacier (No. 14).

1242. Ice cascades, head of Carbon river, mount Rainier. View in the great amphitheater, the gathering point of the Carbon River glacier. On the left of the picture the cliffs rise 6,000 feet to the Liberty cap and the glacier flows out to the right (see number 1240) (No. 17).

1243. Jointed granite, Denny creek, Snoqualmie, Washington. Glacial amphitheater eroded in the granite. The streams of this portion of the Cascade range descend by a series of steps, each of which is attributed to the retrogressive work of glacial action (see number 1245) (No. 55).

1244. Falls on upper Snoqualmie river. View of falls and canyon in metamorphosed grits and slates of Miocene age near the summit of the Cascade range, Snoqualmie pass; elevation 3,000 feet (No. 53).

1245. Falls on Snoqualmie river. Franklin falls about 2 miles west of Snoqualmie pass (No. 52).

1246. The Needles from Poodledog pass, Monte Cristo, Washington. The Needles (see number 1248) are composed of breccia from Twin Lake crater, off to the right. An important mineral vein is the cause of the ravine between them (No. 33).

1247. Pride of the Mountain range, Monte Cristo. This range lies east of Monte Cristo, separating that district from the Goat Lake district. A portion of the high peaks consists of diorite, and they are traversed by numerous metalliferous veins. Their elevation is 6,500 to 7,000 feet (No. 34).

1248. Panorama from Willmann pass (north half), Monte Cristo. The divide between Silver creek, flowing south, and Sauk river, flowing north, at Willmann pass is an arête with an elevation of 4,800 feet. From its crest, looking northeast. Monte Cristo, the mining camp, lies in the canyon in front of the farther range. The Needles and Willmann peak, composed of breccia from Twin Lake crater, rise in the right of the picture (see continuation in 1249) (No. 19).

1249. Panorama from Willmann pass (south half), Monte Cristo. The foreground shows the descent into the "'76" amphitheater leading to Monte Cristo. The high peak in the center is Glacier peak, on the right of which, in the basin 2,500 feet deep, lie Twin lakes. A small glacier extends northward from the peak (No. 18).

1250. Glacier peak, Monte Cristo. View from the same point as number 1249, taken with a narrow angle lens to show details of Glacier peak (No. 36).

1251. Glacier peak from Goat peak, Monte Cristo. From ridge between the crater basin of Twin lakes on the right and the glacial amphitheater leading down to Monte Cristo on the left, looking east. The rocks in the foreground are granite. Glacier peak and near high ridge composed of volcanic breccia. The contact between the two occurs along a vertical plane immediately at the foot of the first ascent from the foreground (see 1257). The flows from Twin Lake crater are distinctly bedded and dip eastward (see 1252) (No. 20).

1252. Cliffs of porphyrite and breccia, Glacier peak, Washington. View from the same point as 1251; taken with a narrow angle lens to show details of bedded and vertical structure in flows from Twin Lake crater (No. 21).

1253. Looking west from Goat peak, Monte Cristo. View of Silver lake and Silver Tip mountain, 1½ miles southwest of Monte Cristo, Washington. The rock of the vicinity is a massive volcanic. The lake occupies a basin, which is presumably a crater, but which may possibly belong to the class of hollows produced by retrogressive glacial erosion. Attention is called to the extremely abrupt peaks characteristic of this portion of the Cascade range (No. 31).

1254. Silver lake, Monte Cristo (see 1252). Near view of Silver lake, showing the outlet and the surrounding cliffs of porphyrite (No. 24).

1255. Looking down Twin lakes, Monte Cristo. General view of Twin lakes about three miles southeast of Monte Cristo. They occupy basins of craters, the largest being about half a mile in length. The rock surrounding them in the foreground, on the right of the picture, is granite, while much of the farther side of the lake and the foreground in the extreme left is volcanic breccia. Spherulitic rhyolite occurs at the east end. The higher cliffs in the vicinity are largely made up of breccia with granite fragments. The foreground exhibits *roches moutonnées* (No. 26).

1256. Upper Twin lake from the east end, Monte Cristo (see 1255). View from the east end of upper Twin lake. The cliff on the right is granite, while the talus in the foreground is composed of blocks of volcanic breccia. Immedaitely behind the camera, cliffs of breccia rise about 2,500 feet to the summit of Glacier peak (see 1251 and 1252) (No. 27).

1257. Volcanic breccia of Twin Lake crater, Monte Cristo (see 251). The camera stands on the arête between Twin lakes and the "'76" amphitheater, looking into the latter. The breccia on the right was erupted from Twin lakes, and is in immediate contact with the granite, of which it contains fragments (No. 25).

1258. Sauk mountain from near Sauk, Washington. It rises abruptly on the western bank of the Skagit river. It is an old volcanic vent, probably represented by a lake which now lies in a deep basin near the summit. The elevation is about 5,800 feet, and the volcanics are erupted through a mass of iron-bearing schist and limestone (No. 41).

1259. Landslide crack, Sauk mountain. On the left of the view the descent is precipitous for 500 or 600 feet. The crack in the middle ground on the right is evidently due to an outward movement of the rock mass toward the cliff, but is now filled with debris to within a few feet of the top (No. 48).

1260. Limestone, Baker River canyon, Washington. View on Baker river half a mile above its junction with the Skagit. The river flows through a canyon which it enters from a broader valley carved in shales. The rock of the canyon is crystalline limestone (No. 43*f*).

1261. Salmon fishing and limestone, Baker River canyon, Washington (see 1260). View looking down Baker River canyon toward the Skagit (No. 44).

1262. Crater lake, mount Rainier; elevation 5,200 feet. View of a lake on the northwest slope of mount Rainier, having a diameter of about half a mile. It is probably a large crater. The rocks are glaciated and their rounded form is shown in the point extending from the group of trees on the right down to the lake (No. 3).

1263. North Puyallup glacier, mount Rainier, from Eagle cliff. General view from same point as number 1264, showing the Puyallup canyon, about 2,000 feet deep, and the Puyallup glacier in the distance (No. 7).

1264. North Puyallup glacier, mount Rainier, from Eagle cliff. General view of the northwestern slope, comprising the Puyallup glacier and the Liberty cap; elevation 14,000 feet. The head of the glacier in the hollow on the left is about four miles away, at an elevation of 10,000 feet. The terminus of the glacier, consisting of two fan-like tongues, is lost in the lower right-hand corner of the picture in the fog (No. 8).

1265. Liberty cap from near Spray falls, mount Rainier. Detailed view of the northwestern slope, showing the central portion of the Puyallup glacier and the precipitous slopes of the Liberty cap, which rises 3,500 to 4,000 feet above it (No. 4).

1266. Evening on the northwestern slope of mount Rainier. View of the snow-fields, with a group of krummholtz in the foreground; elevation about 7,000 feet. The summit of mount Rainier is about four miles distant, and the intervening snow-fields are broken by crops of andesitic lavas and scoriæ. The solid rock surfaces are extensively glaciated (no negative).

1267. Northwestern slope from 10,000 feet, mount Rainier. View of the head of the Puyallup glacier and the Liberty cap, showing details of crevasses and the distribution of snow in August, 1895 (No. 9).

WYOMING

Photographed by C. D. Walcott

5 by 7 inches. Negatives in United States Geological Survey

1268. Big Horn mountains. View of eastward dipping Paleozoic rocks forming eastern summit and slope of the mountains southwest of Sheridan (No 436).

1269. Big Horn mountains. View of cliffs on Bald Mountain road, east of Little Baldy (No. 451).

1270. Big Horn mountains. Eroded granite near Bald mountain, at eastern summit, overlooking valley toward Dayton (No. 464).

Photographed by N. H. Darton

8 by 10 inches. Negatives in United States Geological Survey

1271. Devils tower from south (No. 740).

1272. Devils tower from a mile south; shows base (No. 732).

1273. Devils tower; near view (No. 738).
1274. Devils tower, west side; near view (No. 739).
1275. Columnar structure of phonolite. Inyankara mountain, Crook county, Wyoming (No. 745).
1276. Overturned tree, with roots lifting rock fragments. West side of Black hills, Weston county, Wyoming (No. 748).
1277. Sundance mountain; showing talus cones of trachyte, near Sundance, Wyoming (No. 742).
1278. Sink-hole in Minnekahta limestone east-northeast of Cambria, Wyoming (No. 593).
1279. A typical tepee butte, Weston county, Wyoming, due to limestone lense filled with *Lucina occidentalis*, in Pierre shale (No. 587).
1280. Concretions in Laramie sands, Weston county (No. 595).
1281. Little Sundance dome east of Sundance. Purple limestone and underlying beds uplifted by a laccolite (No. 585).

Photographed by I. C. Russell

6½ by 8½ inches. Negative in United States Geological Survey

1282. Jurassic rocks, Como (Aurora), Wyoming (No. 294).

Photographed by N. H. Darton

8 by 10 inches. Negative in United States Geological Survey

1283. Minerva terrace, Mammoth Hot springs, Yellowstone park (No. 651).
1284. Paint pots near Fountain hotel, Yellowstone park (No. 667).

Photographed by C. D. Walcott

6½ by 8½ inches. Negatives in United States Geological Survey

Yellowstone Park views

1285. Mouth of Fountain geyser shortly before eruption (No. 548).
1286. Mouth of Fountain geyser shortly before eruption (No. 548*a*).
1287. Siliceous deposits in the basin of the Great Fountain geyser (No. 549).
1288. Terrace pools on lower slopes of Angel terrace (No. 550).
1289. Calcareous points covering bottom of pool, Angel terrace, Mammoth hot springs (No. 552).
1290. Calcareous deposits in pool, summit of Angel terrace, Mammoth hot springs (No. 553).
1290*a*. Calcareous (mushroom-like) concretionary deposits, Angel terrace, Mammoth hot springs (No. 554).
1291. Calcareous (mushroom-like) concretionary deposits, Angel terrace, Mammoth hot springs (No. 554*a*).
1292. Calcareous algæ in outlet of pools, summit of Angel terrace, Mammoth hot springs (No. 555).
1293. Angel terrace near Mammoth Hot Springs hotel (No. 515*a*).
1294. View showing method of deposition of the siliceous deposits on slope of hot springs, summit of Angel terrace (No. 516).

1295. View showing method of deposition of the siliceous deposits on slope of hot springs, summit of Angel terrace (No. 516*c*).
1296. "Ox-bow" bend, Trout creek, Hayden valley, Yellowstone park (No. 556).
1297. North end of Teton range, northwest of Jackson lake, Wyoming (No. 557).
1298. View of the Teton range from the east shore of Jackson lake, Wyoming (No. 558*a*).
1299. Waterfall over Cambrian limestone, Sheep creek, toward summit of Teton range, southwest of Jackson lake, Wyoming (No. 541).

Photographed by J. P. Iddings

6½ by 8½ inches. Negatives in United States Geological Survey

Yellowstone Park views

1300. Obsidian columns, Obsidian cliff. Described in the Seventh Annual Report of the United States Geological Survey, 1888, pages 249–295 (No. 65).
1301. The same, showing lithoidal portion (No. 69).
1302. Erratic boulders, Pleasant valley (No. 152).
1303. Glacial boulder, brink of Yellowstone canyon (No. 33).
1304. Hoodoo temple, Hoodoo basin (No. 356).
1305. Hoodoos, Hoodoo basin (No. 354).
1306. Lithophysæ, half a mile above falls on lower Fire Hole river (No. 77).
1307. Lithophysæ, half a mile above falls on lower Fire Hole river (No. 78).
1308. Keplers cascade, Fire Hole river, Upper Geyser basin (No. 11).
1309. Spring in Gallatin canyon, Gallatin range (No. 131).
1310. Emerald Creek falls; basalt cliffs (No. 340).
1311. Tower falls (No. 141).
1312. Rustic falls, Glen lake (No. 83).
1313. Keplers cascade, Fire Hole river, Upper Geyser basin (No. 14).
1314. Natural bridge of rhyolite, Bridge creek (No. 81).
1315. Small geyser in eruption, in Upper Geyser basin (No. 188).
1316. Rustic geyser in eruption, Middle Geyser basin (No. 174).
1317. Runway of Indigo spring (No. 101).
1318. Algæ basins (showing formation of siliceous sinter), Emerald spring, Upper Geyser basin (No. 180).
1319. Spike geyser, Witch creek (No. 177).
1320. Siliceous sinter from Coral spring (No. 363).
1321. Bannock peak, Gallatin range (No. 250).
1322. Yellowstone canyon, opposite Tower falls (No. 144).
1323. Basalt cliff near Tower falls (No. 163).
1324. Petrified tree trunk, Fossil forest (No. 327).
1325. Fossil tree trunks, Fossil forest (No. 325).
1326. Petrified tree trunk. Lamar valley in distance (No. 329).

Photographed by J. K. Hillers

11 by 14 inches. Negatives in United States Geological Survey

Yellowstone Park views

1327. Fire Hole falls (No. 214).
1328. Canyon of Yellowstone from the brink of lower falls (No. 213).

1329. Lower falls of Yellowstone (No. 204).
1330. The Paint Pots (No. 177).
1331. Beehive (No. 191).
1332. Lone Star geyser in eruption (No. 182).
1333. Excelsior geyser (No. 175).
1334. Fountain basin.
1335. Minerva terrace, Mammoth hot springs (No. 172).
1336. The Castle geyser in action. Its well on left; Old Faithful on right beyond (No. 195).
1337. Upper Geyser basin (No. 180).

Photographed by W. H. Jackson

11 by 14 inches. Negatives in United States Geological Survey

Yellowstone Park views

1338. Upper Geyser basin. Crater of Old Faithful in the foreground at the right. In the distance the Castle and Grand geysers are in eruption. The formation is siliceous sinter (No. 932).
1339. Crater of the Castle geyser, Upper Geyser basin. Siliceous sinter (No. 933).
1340. Crater of the Grotto geyser. Siliceous sinter (No. 928).
1341. Old Faithful in eruption. Upper Geyser basin (No. 930).
1342. Mammoth hot springs (No. 944).
1343. Mammoth hot springs (No. 943).
1344. Upper falls and Upper canyon of the Yellowstone (No. 958).
1345. Grand canyon of the Yellowstone (No. 952).
1346. Lower falls of the Yellowstone, 308 feet high (No. 957).
1347. Upper falls of the Yellowstone, 112 feet high (No. 954).

Photographed by W. H. Jackson, Detroit, Michigan

19 by 44 inches

1348. Yellowstone canyon and falls. Mounted, $12; not mounted, $10 (No. 1098*p*).

17 by 38 inches

1349. Mammoth hot springs; Cleopatra and Jupiter terraces. Mounted, $7.50; not mounted, $6 (No. 1661*p*).

21 by 16 inches

1350. Yellowstone canyon. Price, $2.50 mounted ; $2 unmounted (No. 1095).
1351. Pulpit terraces, Mammoth hot springs (No. 1657).
1352. Old Faithful, a geyser in action (No. 1105).
1353. The "Castle" geyser and Crested spring, Yellowstone (No. 1106).
1354. Index peak, Wyoming (No. 1656).
1355. Fremonts peak and lake, Wind River mountains, Wyoming (No. 1669).
1356. Teton range; from the east (No. 1667).
1357. Teton range; from Jacksons lake (No. 1666).
1358. Cloud peak, Big Horn mountains, Wyoming (No. 1653).
1359. Matto tepee, or Devils tower, Wyoming (No. 1651).

Miscellaneous Photographs

Experiments of Bailey Willis in 1890 in Folding Loaded Strata by Horizontal Thrust

The following photographs are selected from a series representing models of folded strata. Negatives in United States Geological Survey. Mostly 18 by 24 inches. Price, 75 cents each, unmounted; $1 mounted on card or muslin. They should be ordered by model letter:

The folds are the results of horizontal pressure applied to the ends of flat strata which were confined on four sides and at the bottom, and could rise only by lifting a load of bird shot.

The materials composing the models were mixtures of plaster of Paris and beeswax and Venice turpentine in varied proportions, which resulted in strata of varied plasticity.

Each pile of strata was compressed from two to five times and photographed at each stage of compression. The photographs therefore represent successive stages in the development of folds and faults.

1360. Model (no letter). Initial form not shown, all the strata having been laid flat. Illustrates the development of original and consequent folds in relatively hard strata on a soft base.

1361. Models A and C. Illustrate the development of anticlines at points of initial dip. The bedded materials are the same in F and C, in both being relatively hard and rigid. This is shown in the acute broken folds. The base is soft. Compare E and G.

1362. Model E. Illustrates development of a primary anticline at a point of initial dip near the applied force, together with the growth of a consequent fold. The bedded materials are softer than in model F. Compare G.

1363. Model E 1. Illustrates the development of 3 anticlines, two of which developed at points of initial dip remote from the applied force. The third grew near the applied force iu consequence of swelling of the soft base. The materials are the same as in model E. Compare G 1.

1364. Model G. Illustrates the growth of folds from an initial form like Model E, but in softer materials.

1365. Model G 1. Illustrates the growth of folds from an initial form like E 1, but in softer materials.

1366. Model H. Illustrates the development of anticlines from a form like G 1, but with a softer base beneath the bedded materials.

1367. Model K. Illustrates the effects of compressing conformable strata accumulated in a deep syncline of deposition, there being a controlling competent stratum and thin-bedded strata of softer and harder substances which developed minor folds and thrusts.

1368. Model L. L is the complement of K, being similar in form and materials, but having been shortened from the opposite end. The applied energy was used up in developing the folds, and did not affect the distant initial dips.

1369–1371. Model M. Illustrates the development of diverse structures in two competent series, one at the base and one at the top, and in the intermediate soft incompetent material.

1372, 1373. Model M. Two stages, full size of model for class use.

1374–1376. Model J. Three stages, full size of model, illustrating development of an overthrust fault in soft strata beneath a harder series, and also accommodation of constant volume to change of form by shearing in two systems and displacement of triangular prisms.

1377. Model J 1. Two views of one stage, large scale, illustrating major folds longitudinally related to thrusts.

Photographed for G. P. Merrill, United States National Museum

8 by 10 inches

1378. Hypothetical map of the North American continent during the period of maximum glaciation, in early Pleistocene time.

1379. Hypothetical map of the North American continent at the close of Neocene time.

1380. Hypothetical map of the North American continent in Middle Cretaceous time.

1381. Hypothetical map of the North American continent at the close of Carboniferous time.

1382. Hypothetical map of the North American continent in early Carboniferous time.

1383. Hypothetical map of the North American continent in early Devonian time.

1384. Hypothetical map of the North American continent in earliest Silurian time.

1385. Hypothetical map of the North American continent in early Lower Cambrian time.

1386. Hypothetical map of the North American continent during late Algonkian time.

Photographed by J. S. Diller

6½ by 8½ inches. Negatives in United States Geological Survey

1387. Hon. C. D. Walcott, Director United States Geological Survey; Major J. W. Powell, Director United States Bureau of Ethnology; Sir Archibald Geikie, Director of Geological Survey of Great Britain (No. 359 G).

1388. Geikie excursion party, Jefferson rock, Harpers ferry, West Virginia, May, 1897 (No. 358 G).

1389. Geikie excursion party, Jefferson rock, Harpers ferry, West Virginia, May, 1897 (no negative).

1390. Geikie excursion party, Jefferson rock, Harpers ferry, West Virginia, May, 1897 (No. 360 G).

Photographed by the late Dr G. H. Williams, of Johns Hopkins University, Baltimore, Maryland

4½ by 6½ inches

Photographs of laboratory specimens

1391. Anticlinal fold; Animikee slate, Pigeon point, lake Superior.

1392. Folded hala-flinta; Naerodal, Norway.

1393. Gneiss; Stony Point-on-the Hudson, New York.

1394. Slate, showing bedding, cleavage and rigid calcareous layer, Bangor, Pennsylvania.

1395. Quartz-schist, with stretched tourmaline, Shoemaker's quarry, Baltimore, Maryland.

Photographed by G. P. Merrill, National Museum, Washington, D. C.

8 by 10 inches

1396. Slate, showing cleavage and faulting, Bangor, Pennsylvania.

1397. Gneiss, Lawrence and West Andover, Massachusetts.

Photographed by S. Calvin, Des Moines, Iowa

8 by 10 inches

1398. A crowded field of foraminifera with medium-sized *Textularia*, and many specimens of *Anomalina* magnified 55 diameters; from Saint Helena, Nebraska.

Photographed for G. P. Merrill, United States National Museum, Washington, D. C.

8 by 10 inches

1399, 1400. Two photographs of faulted sandstone in National Museum. Samples collected by N. H. Darton.

6½ by 8½ inches

1401. Polished slab of orbicular granite in the collection of the United States National Museum. From Slattemösse, Smaländ, Sweden. Dimensions, 22 by 30 inches.

Photographed by J. K. Hillers

8 by 10 inches. Negatives in United States Geological Survey

1402. Striated limestone boulder from loess, one-half natural size, Norway, Iowa. Published in Eleventh Annual Report United States Geological Survey, plate xlvi (No. 365).

Photographed by G. P. Merrill, United States National Museum, Washington, D. C.

1403. Pyroxenite nodules, partially altered into serpentine, Montville, New Jersey.

Photographed by E. B. Harden for Geological Survey of Pennsylvania

5 by 8 inches. Negatives deposited in United States Geological Survey, Washington, D. C., with Harden's numbers

1404. *Pseudopecopteris macilenta* (L. and H.) Lx. Upper Pottsville series, Washington county, Arkansas. *Lepidocystis* (Polysporia) *salisburyi* Lx. Pottsville series, Days gap, Alabama (No. 1559).

1405. *Sphenopteris* (Hymenophyllites) *pendulata* Lx. MSS. (Fertile.) *Lepidophyllum alabamense* D. W. MSS. Pottsville series, Cordova, Alabama (No. 1560).

1406. *Pseudopecopteris obtusiloba* (Stb.) Lx., var. *dilatata* Lx. MSS. Kanawha series, West Virginia (No. 1561).

1407. *Pseudopecopteris obtusiloba* (Stb.) Lx. Kanawha series, West Virginia (No. 1562).

1408. *Dictyopteris sub-brongniartii* Gr. Ey. Coal Measures (Westphalien), France (No. 1563).

1409. Spirophyton. A probable Pseudophyte. Lower Carboniferous, near Warren, Pennsylvania (No. 1564).

1410. *Asterophyllites gracilis* Lx. Fruiting spikes. Pottsville series, Dade county, Georgia (1565).

1411. *Arthrophycus harlani* (Conr.) Hall. Medina sandstone. Locality unknown (No. 1566).

1412. *Arthrophycus harlani* (Conr.) Hall. Probably from Medina sandstone. Locality unknown (No. 1567.)

1413. *Callipteridium tracyanum* Lx. Upper Pottsville (Walden SS), Tracy City, Tennessee (No. 1568).

1414. *Neuropteris clarksoni* Lx. High anthracite coal ("G"), Olyphant, Pennsylvania. Photograph reduced (No. 1569).

1415. Pseudophyte. Casts of trails of molluscs. Formation and locality unknown (No. 1570).

1416. *Eurypterus mansfieldi*, Hall. Figured in Second Geological Survey of Pennsylvania, page 3, plate 5, figure 3. Specimen from just below Darlington cannel coal, near Cannelton, Darlington county, Pennsylvania (No. 1571).

1417. Natural casts of Atrypa, Spinosa, Spirifer, Rhynchonella, Pelicypods, and Tentaculites. Horizon, Hamilton. A splendid illustration of associated Hamilton species (No. 1572).

1418. Natural sections of spire-bearing Brachiopods; also a few Tentaculites preserved. Horizon probably Lower Helderberg (No. 1573).

SUBJECT CATALOG

Ant Hill

425. Ant hill at Pueblo, Colorado.

Bad Lands

128. Limestone ridge and gully, weathering, Bettles river, Alaska.

682, 683. Scotts Bluff, Nebraska.

691. Northeast of Chadron, Nebraska.

688, 692, 693. Toadstool park, near Adelia, Sioux county, Nebraska.

695. Titanotherium sands east of Adelia, Nebraska.

1066, 1067. Titanotherium beds, Corral draw, edge of Big Bad lands of South Dakota.

1068. Big Bad lands, Protoceras sandstones on Oreodon clays, head of Indian draw, South Dakota.

1069. Big Bad lands, Protoceras sandstone area, head of Cottonwood draw, South Dakota.

1070. Big Bad lands, Indian draw, South Dakota.

1071. Big Bad lands, spur of Sheep mountain, South Dakota.
1072, 1073. Big Bad lands, south end of Sheep mountain and Devils tower, South Dakota.
1090. Big Bad lands, columns capped by sandstone, Cedar draw, South Dakota.
1091. Big Bad lands, erosion forms in Titanotherium sands, Cedar draw, South Dakota.
1092. Big Bad lands, columns of sandy clay capped by sandstone, Cedar draw, South Dakota.
1093. Big Bad lands, Oreodon beds between Battle draw and Cedar draw, South Dakota.
1094. Big Bad lands, Titanotherium beds and Oreodon beds, Battle draw, South Dakota.
1075–1081. Protoceras sandstone area, Big Bad lands, South Dakota.
1082–1087, 1089. Big Bad lands of South Dakota near Flour trail.
1088. Big Bad lands at Corral draw, South Dakota.
1166. Irwin Bass place, south of Mosley junction, Virginia.
1304, 1305. Hoodoo basin, Yellowstone park, Wyoming.

BEACH DEPOSITS

(See also Shore Cliffs)

316. Swampy island, old beach, lake Winnipeg, Manitoba.
320. Ice-pressed boulder pavement, Red Deer lake, Saskatchewan, Northwest Territory.
325. Magdalen river and bay, lower Saint Lawrence, Canada.
350. Imbricating beach pebbles, bay of Fundy, New Brunswick
353, 354. Mud flats, bay of Fundy.
635. Beach of limestone pebbles, Mackinaw island, Michigan.
636. Gravel spit, Mackinaw island, Michigan.
637. Spit, Bois Blanc island, Michigan.
638. Spit of shingle, Au Train island, lake Superior.
639. Curved sand spit, straits of Mackinaw.
783. Shore of lake Ontario at Wilson, New York.
640. A recurved spit, Grand Traverse bay, lake Michigan, Michigan.
641. Bar at Sleeping Bear bluff, east shore of lake Michigan.
737, 738. Griffin bay, shore of lake Ontario, New York.
739. West shore, Cayuga lake, at East Varick, New York.
742–744. Iroquois beach, New York.
747. Shore of lake Ontario, Niagara county, New York.
748. Beach of flat shingle, lake Ontario, New York.
749. Beach of well-rounded shingle, lake Ontario, New York.
750. Cemented shingle, Lewiston, New York.
751, 752. Section of spit of glacial lake, Lewiston, New York.

CANYONS

116. Foot of Woods canyon on Copper river, Alaska.
131. Canyons in young rock series, one mile below Tramway bar, Alaska.
150. Grand canyon of the Colorado, Arizona.

151. Grand canyon of the Colorado at the foot of the Toroweap in Arizona.
152. Shinimo altar from the brink of Marble canyon of the Colorado river, Arizona.
153. Canyon de Chelly, Arizona.
154. Walnut canyon, Arizona.
158, 172. Yosemite Falls cliff, California.
159. The Sentinel, Yosemite valley, California.
160, 161, 169. El Capitan, Yosemite valley, California.
162. Washington column, Yosemite valley, California.
163, 167. Home of the Storm Gods, Yosemite valley, California.
164. Three Graces, Yosemite valley, California.
165, 166. Royal Arches, Yosemite valley, California.
168. Yosemite valley, California.
170. Cathedral spires, Yosemite valley, California.
171. Shingle, Yosemite, California.
173. Three Brothers, Yosemite valley, California.
182. Cliffs above Mirror lake, Yosemite valley, California.
193–198. Kings river, California.
222. Lake canyon near Mono lake, California.
308. Fraser river, Fountain, British Columbia.
311. Gorge of Elk river, British Columbia.
341. Canyon below the Grand falls of Labrador.
441. Acowitz canyon, Colorado.
613. The gorge of the lower Susquehanna.
615. The Potomac near Harpers ferry.
616. Junction of the Shenandoah and Potomac.
617. The Shenandoah near Harpers ferry.
800. Enfield gorge, near Ithaca, New York.
831. Gorge at Trenton falls, New York; lower portion.
869, 870, 872, 889. Ausable chasm, New York.
884, 895. West Point, New York; looking northward from plain.
874. Lower Ausable lake, Adirondacks, New York.
894. Avalanche lake, Adirondacks.
897. Hudson river; looking north from fort Putnam.
920–925. The French Broad river, North Carolina.
988. Water-sheet narrows, Pennsylvania. Juniata river.
999. Delaware water gap.
1123. Canyon in Sioux quartzite, Dell rapids, South Dakota.
1125. Palisades on Split Rock creek, South Dakota.
1128, 1129. Doe River gorge, Tennessee.
1217. Stehekin valley, east of Cascade pass, Cascade range, Washington.
1236. Canyon-like gorge occupied by lake Chelan, Washington.
1244. Canyon in metamorphosed grits and slates of Miocene age, Upper Snoqualmie river, Washington.
1260, 1261. Baker River canyon, Washington.
1313. Keplers cascade, Fire Hole river, Yellowstone park, Wyoming.
1322. Yellowstone canyon opposite Tower falls, Wyoming.
1327. Fire Hole falls, Yellowstone park, Wyoming.
1328. Canyon of Yellowstone from the brink of lower falls, Yellowstone park, Wyoming.

1344. Upper falls and canyon of the Yellowstone, Yellowstone park.
1345, 1350. Grand canyon of the Yellowstone.
1348. Yellowstone canyon and falls.
1350. Yellowstone canyon.

Castellated Erosion Forms

152. Shinimo altar, Grand canyon of the Colorado.
153. Canyon de Chelly, Arizona.
155. Navajo church near Fort Wingate, New Mexico.
159. The Sentinel, Yosemite valley, California.
217. Towers of calcareous tufa formed by sublacustral springs, shore of Mono lake, California.
406, 407. Triassic sandstone, Garden of the Gods, Colorado.
408. Cathedral spires, Garden of the Gods, Colorado.
445–449. Effects of rain erosion on horizontally bedded andesite conglomerate, headwaters of Rio Grande river, Colorado.
677, 678. Eroded, cross-bedded Cretaceous sandstone, north of north fork of Sun river, Teton county, Montana.
681. Scotts bluff, Nebraska.
697. Jail and court-house, Cheyenne county, Nebraska.
698. The jail, looking east, Cheyenne county, Nebraska.
699. "Chimney rock," Cheyenne county, Nebraska.
701, 702. "Smokestack," Banner county, Nebraska.
703. "Twin Sisters," Banner county, Nebraska.
1068. Protoceras sandstones on Oreodon clays, head of Indian draw, Big Bad lands, South Dakota.
1069. Protoceras sandstone area, head of Cottonwood draw, Big Bad lands, South Dakota.
1071. Spur of south end of Sheep mountain, Big Bad lands, South Dakota.
1072, 1073. South end of Sheep mountain and Devils tower, Big Bad lands, South Dakota.
1074. Protoceras sandstone on Oreodon beds near Wounded Knee creek, South Dakota.
1090, 1092. Columns capped by sandstone, White River formation, east side of Cedar daw, Big Bad lands, South Dakota.
1097, 1098, 1107, 1108. Granite needles near Harney peak, Black hills, South Dakota.
1075–1081. Protoceras sandstone area, Big Bad lands, South Dakota.
1086. Sandstone lenses near Flour trail, Big Bad lands, South Dakota.
1087. Columns of clay capped by sandstone near Flour trail, Big Bad lands, South Dakota.
1088. South fork of Corral draw, Big Bad lands, South Dakota.
1122. Needle point, Elk canyon, Black hills, South Dakota.
1246. The Needles from Poodledog pass, Monte Cristo, Washington.
1270. Eroded granite near Bald mountain, Big Horn mountains, Wyoming.
1271–1274. Devils tower, Wyoming.
1304, 1305. Hoodoo basin, Yellowstone park, Wyoming.

CAVE INTERIORS

565-571, 573-582. Mammoth cave, Kentucky.
572, 584, 585. Wyandotte cave, Kentucky.
586, 587. Marengo cave, Kentucky.
882, 883. Howes cave, New York.
1196-1207. Caverns of Luray, Virginia.

CHERT AND FLINT

271. Chert in limestone west of Big Pine, Inyo county, California.
346. Chert in sillery below Quebec, Canada.
554. Niagara limestone, Lyons, Iowa.
1137. Koontz series, Texas.
1146. Flint nodules in chalk, south bank of Colorado, Texas.

COLUMNAR STRUCTURE

280. Laminated and roughly columnar fine-grained pyroxene-andesite, Franklin Hill, California.
300. Glaciated andesite, Alpine county, California.
393. Granite in canyon of Animas river, opposite Ten-mile creek, Colorado.
461. Hawaii.
721. Basaltic columns and bedded trap in gorge of Passaic river at Paterson, New Jersey.
724. Falls of the Passaic, Paterson, New Jersey.
725. Palisades of the Hudson, north from Englewood cliffs.
726-731. Columnar basalt, O'Rourke's quarry, near Orange, New Jersey.
732. Basalt, showing columns of cooling, near Orange, New Jersey.
1271-1274, 1359. Devils tower, Wyoming.
1275. Columnar structure of phonolite, Inyankara, Wyoming.
1300, 1301. Obsidian columns, Obsidian cliff, Yellowstone park, Wyoming.
1323. Basalt cliff near Tower falls, Yellowstone park, Wyoming.

CONGLOMERATES (NEAR VIEWS ONLY)

191. Igneous pudding stone north of Yosemite valley, California.
349. Conglomerate in Sillery beds below Quebec, Canada.
445. Andesite conglomerate, head of Rio Grande, Colorado.
657. Laramie conglomerate, Montana.
680. Arikaree beds southeast of Gering, Nebraska.
813, 814. Boulders in Algonkian, Washington county, New York.
826, 827. Potsdam conglomerate, Saratoga county, New York.
1148. Carboniferous and Permian, Hurricane cliff, Utah.
1157. Calciferous conglomerate near High Gate falls, Vermont.

CONCRETIONS

599. In Matawan formation, Magothy river, Maryland.
601. Ferruginous concretions in Potomac formation, Baltimore, Maryland.

1041. Concentric weathering in shale, Beaver, Pennsylvania.
1106. Cone-in-cone concretion in Pierre shales near Hot springs, South Dakota.
1280. Concretions in Laramie sandstone, Weston county, Wyoming.

Contacts of Igneous Rocks (near views only)

452. Trap sheet on underlying shales, Hartford, Connecticut.
659. Basic granite and acid granite, Butte, Montana.
721. Base of first Watchung trap sheet in gorge of Passaic river at Paterson, New Jersey.
722. Lateral ascent of base of palisade trap across shale at Kings point, Weehawken, New Jersey.
723. Cross-section exposure of base of palisade trap sheet with Newark shales, Weehawken, New Jersey.

Creep Striæ

1009, 1010. On roofing slate, Bangor, Pennsylvania.

Cross-bedding

154. Bedding and cross-bedding in Walnut canyon, Arizona.
155. Navajo church near fort Wingate, New Mexico.
520. Coal Measures sandstone, Redrock, Marion county, Iowa.
529. Leclaire limestone, obliquely bedded below, horizontally bedded above. Sugar Creek lime quarries, Cedar county, Iowa.
530. Oblique bedding in Leclaire limestone, half a mile south of Leclaire, Iowa.
541. In sandstone, Saint Louis, Bellefontaine, Makaska county, Iowa.
677, 678. Cretaceous sandstone, Teton county, Montana.
679. Conglomerate sandstone lens in Brule clay, 6 miles south from Gering, Nebraska.
696. Dakota sandstone, Bennett, Nebraska.
755. Cross-bedding in sand kame, Lockport, New York.
780. In Medina sandstone, in quarry near Lewiston, New York.
1103. Oligocene cross-bedded gravel, south of Fairburn, South Dakota.
1124. In Sioux quartzite, Sioux Falls, South Dakota.

Crystals in Rocks

251, 252. Quartz in lava near Snag lake, California.
297. Porphyritic granite near Granite lake, Tuolumne county, California.
1397. Gneiss, Lawrence and West Andover, Massachusetts.

Deltas

10. Delta in Gastineau channel, at Juneau, Alaska.
20. Yahtse river from above ice-tunnel, Alaska.
26. Alluvial fan of the Yahtse, Alaska ; 6 by 8 inches.
51. Delta of subglacial stream, Muir glacier, Alaska.
111. Mouth and delta of Chettyna river, mount Blackburn, Alaska.
1233. Delta of Chelan river at its junction with the Columbia, Washington.

DIKES, IGNEOUS

285. Granite at Granite lake, Tuolumne county, California.
287. Basalt dikes, Polka flat, Sierra county, California.
591. Trap dikes at Bald cliff, Maine.
819–820. Fault and dyke, East Canada creek, New York.
893. Trap dike, Avalanche lake, New York.
913. Decomposed trap, Wadesborough, North Carolina.
959. Trap at Cornwall, Pennsylvania.
1120. Bear butte, Black hills, South Dakota.
1152. Trap in Cambrian quartzite, Burlington, Vermont.

DIKES, SANDSTONE

209, 215, 216. Penetrating Cretaceous shales, Dry creek, Tehama county, California.
210. On Roaring river above Drews, California.
211. On Crow creek, Shasta county, California.
212. Cutting Cretaceous shales on Roaring river, Shasta county, California.
213, 214. Group on north fork of Cottonwood creek, near Gaspoint, Shasta county, California.
279. Limestone with intruded quartzite, Waucobi canyon, Inyo county, California.
1101. In Benton shales, southeast of Maitland, South Dakota.

DISMAL SWAMP

1172–1187. Dismal swamp, Virginia.

EARTHQUAKE PHENOMENA

1045–1065. At Charleston, South Carolina.

EXPERIMENTS IN FOLDING LOADED STRATA IN HORIZONTAL THRUST

1360–1378. Experiments of Bailey Willis in 1890. Photographs representing excessive stages in the development of folds and faults.

FAULTS

92. Graywacke, shale and sandstone, Gens de Large river, Alaska.
156. East side of Rio Verde, Arizona.
272, 273. Thrust beds of Cambrian limestone and quartzitic sandstone, Waucobi canyon, Inyo range, California.
274. Thrust plane in south wall of Devils gate, Inyo range, California.
293. Fault scarp, Plumas county, California.
348. Fault between Archean gneiss and Trenton limestone and Utica shales, south of Montmorency falls, Canada.
423. A cliff due to a fault, Las Animas county, Colorado.
514–516, 518. Faulted sandstone and shale, near Houston, Indian Territory.
594. Earlier Columbia gravels and loams on crystalline rocks, east of Rock Creek bridge, Washington, District of Columbia.
690. Gering formation in railroad cut south of Crawford, Nebraska.

716. Rhyolite-tuff in the foothills of the Silver Peak range, Nevada.
819, 820. East bank of East Canada creek, Herkimer county, New York.
841. Overturn and fault of Sprayt creek near South Bethlehem, New York.
912. In sandstone and shale of the Newark system, Bogan cut, near Wadesborough, North Carolina.
1110. In Middle Jurassic sandstone near Buffalo gap, Black hills, South Dakota.
1105. Jura on Trias, south of Hot springs, South Dakota.
1142. In limestone in Bee Spring series, Texas.
1143. In limestone in Barton Creek series, Texas.
1153. Overthrow of Cambrian sandstone on Utica slate, Lone Rock point, near Burlington, Vermont.
1160. In rocks of lower Cambrian and lower Ordovician age near Highgate springs, Vermont.
1161, 1164. North side of river below Highgate falls, Vermont.
1212. Anticline and thrust fault in Tuscarora quartzite, Panther gap, Virginia.
1394. Slate from Bangor, Pennsylvania.
1399, 1400. Samples of faulted sandstone from Black hills.

FISSURES (NOT IN LAVA)

301. Fissures in granite, Charity valley, Alpine county, California.
1259. Landslide crack, Sauk mountain, Washington.

FLEXURES (INCLUDING CREEP)

235. Contorted lake beds near southern margin of Mono lake, California.
253. Overturned fold in Cambrian quartzites, north side of Silver canyon, White Mountain range, Inyo county, California.
258. Syncline in Cambrian, Inyo county, California.
271. Plicated layers of thin bedded chert in limestone etched by erosion, hill near Big Pine, Inyo county, California.
279. Folded limestone and intruded quartzitic sandstones near Devils gate, Waucobi canyon, Inyo range, California.
313. Folded Cretaceous rocks, headwaters of Cascade river, Alberta, British Columbia.
331. Pre-Cambrian distorted schists, Shipton, Canada.
332–336. Twisted gneiss, southern shore of Ottawa river, opposite Montebello and Papineauville, Canada.
344. Anticline in Lévis terrane, above Lévis railway station, province of Quebec, Canada.
345. Plication of shales and sandstones of Sillery terrace, below Quebec, Canada.
506, 507. Limestone in Chicago drainage canal, Illinois.
513. North end of Ozark uplift, Indian territory.
514–519. Flexed and faulted beds near Houston, Indian territory.
768. Post-Glacial anticline, Hopkins creek, Niagara county, New York.
789. Fractured post-Glacial anticline near Syracuse, New York.
797. Section of anticlinal ridge near Dunkirk, New York.
842. Anticline in Esopus shales, Catskill creek, near Leeds, New York.
849–851. Arch in Salina and Clinton beds at High Falls, New York.
957. Old quarry number 2 at Slatington, Pennsylvania.

964. Contorted gneiss, Schuylkill river near Lafayette station, Pennsylvania.
965, 1004. Cut on Schuylkill Valley railroad, showing "creep," Pennsylvania.
990. Syncline in mammoth beds, Hollywood colliery, Hazelton, Pennsylvania.
1001, 1002. Contorted gneiss, Spring Mill, Montgomery county, Pennsylvania.
1003. Anticline on Schuylkill river near Port Clinton, Pennsylvania.
1008. Contorted gneiss of Wissahickon creek, Pennsylvania.
1012. Stripping at Hollywood colliery, Hazelton, Pennsylvania.
1028. Fold in slate quarry, Bangor, Pennsylvania.
1031, 1032. Shales broken down by superincumbent weight or creeping near Columbia, Lancaster county, Pennsylvania.
1038. Synclinal fold in Cambrian limestone, York, Pennsylvania.
1042. Cambrian limestone, Earnest station, near Morriston, Pennsylvania.
1044. Potsdam quartzite, Smith's quarry, Edge Hill, Montgomery county, Pennsylvania.
1130. Folds in Cambrian near Hampton, Tennessee.
1131. Compressed anticlinal fault plane in Nashville sandstone, Little River gap, Tennessee.
1133. Cliff of Cambrian sandstones, southern side of Doe River gorge, near Hampton, Tennessee.
1162. Plicated slates, near Wells post-office, Rutland county, Vermont.
1163. Summit of anticlinal fold, near West Arlington, Vermont.
1193, 1194. Contorted and plicated slaty limestone, bed of Cedar creek, near Natural bridge, Virginia.
1195. Folds in Cambrian shales, northern bank of Cedar Creek, near Natural bridge, Pennsylvania.
1209, 1210. Arched strata on Chesapeake and Ohio canal, near Hancock, West Virginia.
1211. Anticline in Lewiston limestone, South branch of Potomac river, near Hopeville, West Virginia.
1212, 1213. Anticline of Tuscarora quartzite, Panther gap, Virginia.
1214. Arch of Upper Silurian quartzite forming the "Rainbow" at Iron gate, near Clifton forge, Virginia.
1215. Overthrown fold of Upper Silurian quartzite in Eagle mountain, Virginia.
1391. Anticlinal fold, Animikee slate, Pigeon point, lake Superior.
1392. Folded Halla-flinta, Naerodal, Norway.
1393. Gneiss, Stony Point-on-the-Hudson, New York.
1394. Slate, showing bedding, cleavage, and rigid calcareous layer, Bangor, Pennsylvania.
1395. Quartz-schist with stretched tourmaline, Shoemaker's quarry, Green Spring valley, Baltimore county, Maryland.
1396. Slate, showing cleavage and faulting, Bangor, Pennsylvania.

Fossils

328. Carboniferous rocks, southern shore, Joggins, Nova Scotia, showing erect Sigillaria
597. Shell beds in Chesapeake formation on Patuxent river, Jones' wharf, Saint Marys county, Maryland.
685. Daemonelix beds in Loup Fork formations near head of Little Monroe canyon, Sioux county, Nebraska.

1095. Fossil tree in Lower Cretaceous sandstone near Minnekahta station, southern Black hills, South Dakota.
1145. Exogyra in Shoal creek, Texas.
1324–1326. Petrified tree trunks, Fossil forest, Yellowstone park, Wyoming.
1398. Foraminifera, etcetera, from chalk, Saint Helena, Nebraska.
1404–1418. Collection of Second Geological Survey of Pennsylvania (see main catalog for list).

GEYSERS, YELLOWSTONE PARK, WYOMING

1285, 1286. Fountain geyser before eruption.
1315. Small geyser in eruption, Upper Geyser basin.
1316. Rustic geyser in eruption, Middle Geyser basin.
1319. Spike geyser, Witch creek.
1331. Beehive geyser.
1332. Lone Star geyser in eruption.
1333. Excelsior geyser.
1334. Fountain basin.
1336, 1339, 1353. Castle geyser.
1337, 1338. Upper Geyser basin.
1340. Crater of Grotto geyser.
1341, 1352. Old Faithful in eruption.

GLACIERS

5, 6. Hidden glacier, Alaska.
11. Mount Saint Elias, from Samovar hills, with Agassiz glacier, Alaska.
12. Mount Saint Elias, southern face, Alaska.
13. Ice cascade in Agassiz glacier, with new snow, Alaska.
14. Cascade in the névé of Newton glacier, Alaska.
15. Cascade in névé of a tributary of Agassiz glacier, Alaska.
18. Mount Saint Elias from Malaspina glacier, Alaska.
21, Yahtse river issuing from a tunnel in Malaspina glacier, Alaska.
22. Moraine-covered surface of Malaspina glacier, Alaska.
23. Surface of Malaspina glacier.
25. South margin of Malaspina glacier.
28. Tree broken by recent advance of Malaspina glacier, Alaska.
29. Vegetation about southern border of Malaspina glacier, Alaska.
30. Forest growing on margin of Malaspina glacier, Alaska.
33. Vegetation on Malaspina glacier, Alaska.
34–46, 51–57, 62, 65–69, 71, 73–81, 83–85. Muir Glacier region, Alaska.
77, 78. Junction of Girdled with Muir glacier, Alaska.
97. Chugatch mountains, Alaska.
101, 103, 105, 106. Valdes glacier, Alaska.
115. Cleve valley, from moraine near foot of glacier, Alaska.
123. Front of Woodworth glacier, showing topography of moraine-covered ice-front on Tasnuna river, Alaska.
124. Woodworth glacier, near foot, where cut by Tasnuna river.
146, 147. (Panorama.) View across Glacier creek, valley of upper Snake river near Nome, Alaska.

199, 200, 204. Mount Shasta from a distance.
201. Mount Shasta, near view.
202. Whitney glacier, crevasses, and moraine, northwestern slope of mount Shasta, California.
203. Bulam glacier and moraine, northern slope of mount Shasta, California.
205. Hotlum glacier and moraine, eastern slope of mount Shasta, California.
223. Mount Lyell from the Tuolumne meadows, California.
228. Mount Dana, California, small glacier on northern slope.
229–231. Mount Dana glacier.
232, 233. (Panorama.) Mount Lyell glacier, northern side of mount Lyell, California.
312. Glacier and snow-field at head of Red Deer river, Alberta, Canada.
625. Porfirio Diaz glacier, Ixtaccihuatl, Mexico.
676. Glacier on Mission range, Montana.
1218. Remnants of glaciers, Cascade pass, Cascade range, Washington.
1221. Glacier and basin at head of Stehekin river, Cascade pass, Cascade range, Washington.
1223, 1224. Typical glacier of the northern Cascade range, showing névé and incipient ice-stream with crevasses, Cascade pass, Cascade range, Washington.
1226. Typical glacier of the high Cascades, showing crevassing and terminal moraines, Cascade pass, Cascade range, Washington.
1240. Carbon River glacier, mount Rainier, Washington.
1241. Flora east of Carbon River glacier, mount Rainier, Washington.
1242. Ice cascades, head of Carbon river, mount Rainier, Washington.
1250. Glacier park, Monte Cristo, Washington.
1263, 1264. North Puyallup glacier, mount Rainier, Washington, from Eagle cliff.
1265. Liberty cap from near Spray falls, mount Rainier, showing Puyallup glacier.
1266. View toward mount Rainier.
1267. Puyallup glacier and Liberty cap, mount Rainier.

GLACIAL DEPOSITS

(See also Glacial Topography)

4. Drift-strewn surface, Glacier bay, Alaska.
5. Section of moraine ridge on Hidden glacier, Alaska.
6. New kettle-hole in gravel, Hidden glacier, Alaska.
7. Gravel waste plain and incipient kettle hole, Hidden glacier, Alaska.
8. Push moraine, Crillon glacier, Alaska, showing disturbed forest.
9. Push moraine, Columbia glacier, Alaska.
16. Canyon in Chaix hills; stratified moraine with recent shells, Alaska.
18. Marginal drainage of Malaspina glacier, Alaska.
19. Abandoned lake beds near Chaix hills, Alaska.
22. Moraine-covered surface of Malaspina glacier, Alaska.
31. Alluvial fan or eskar stream, Malaspina glacier, Alaska.
35, 41, 42, 47–50, 58, 60, 63, 64. Muir Glacier region, Alaska.
58, 59. Buried forest near Muir glacier, Alaska.
63, 64. Muir glacier overriding stratified deposits, Alaska.

84. Stream terrace at end of Muir glacier, Alaska.
101. Moraine-covered crevasse ridge, foot of Valdes glacier, Alaska.
102. Terminal moraine in front of Valdes glacier, Alaska.
104. Looking south from Valdes.
108. Silt bluffs on east side of Klutena river, Alaska.
123. Topography of moraine-covered ice-front, Woodworth glacier.
201. Terminal moraines of the Whitney and the Bulam glaciers, mount Shasta, California.
203. Bulam glacier and moraine, mount Shasta, California.
205. Hotlum glacier and moraine, mount Shasta, California.
207. Moraine of late glacial field at western base of Lassen peak, California.
218. Perched boulder near Jura lake, Mono valley, California.
302. Moraines north of Pleasant valley, Alpine county, California.
308. Fraser river at Fountain, British Columbia.
314. Bluffs at Lethbridge, Alberta.
428. Moraine, Longs peak, Colorado.
502–505. Drift, sections 5, 6, 7, Chicago drainage canal, Illinois.
507. "Clay pocket," section 10, Chicago drainage canal.
526. Till interbedded in loess, north of Sioux City, Iowa.
533. Buchanan gravels, cross-bedded sands and gravels; Iowan drift and boulders of Kansan drift type.
534. Granitic boulders of Iowan drift near Winthrop, Iowa.
543. Mount Vernon paha.
620. Ship rock, Massachusetts, a glacial-drift boulder at Peabody.
717. Churchill rock, Nottingham, New Hampshire. A glacial-drift boulder on Pawtuckaway mountain.
658. Morainal debris; characteristic of moraine of Crazy mountains, Montana.
718. Washington boulder, Conway, New Hampshire.
719. Bartlett boulder, New Hampshire.
735. Perched block of sandstone on Palisade ridge, east of Englewood, New Jersey.
755. Cross-bedding in kame, near Lockport, New York.
756. Till shore of lake Ontario, New York.
757. Deposit of torrent of Erian water, Lockport, New York.
759. Angular gravel in kame, south of Royalon, Niagara county, New York.
811. Cut in drift near Gravesville, New York.
898–900. Drift boulder, Bronx park, New York city.
903. Rocking stone in Bronx park, New York city.
904. Perched rock near mount Kisco in Westchester county, New York.
905. Boulder clay, near site of Columbia University, New York city.
974, 975. Glacial till and boulder at the Bangor slate quarry at Bangor, Northampton county, Pennsylvania.
977. Boulder of Pottsville conglomerate on crest of Penobscot mountain, Luzerne county, Pennsylvania.
983. Castle rock, Edgemont township, Delaware county, Pennsylvania.
1238. Drift dam, east end of lake Chelan, Washington; shows stratification.
1302. Erratic boulders, Pleasant valley, Yellowstone park, Wyoming.
1303. Glacial boulder, brink of Yellowstone canyon.

Glacial Lakes

41. Rock basin, Muir glacier, Alaska.
184. Crescent lake, Yosemite, California.
278. Lake on north fork of Big Pine creek, Inyo county, California.
299. Granite lake, Tuolumne county, California.
431. Lake near Longs peak, Colorado.
656. Lake at head of Little Timber creek, Crazy mountains, Montana.
676. Glaciers on Mission range, Montana.
1253, 1254. Silver lake, near Monte Cristo, Washington.
1222. Doubtful lake, Cascade range, Washington.

Glacial Scratches, Furrows, Etcetera

82. Scratches at north end of Sebree island, Alaska.
192. Granite surface near Johnson lake, Yosemite valley, California.
208. Glacial striæ, north Yallobally mount, Coast range, California.
525. Glacial scorings, Kingston, Des Moines county, Iowa.
733. *Roche Moutonnée* (trap) near Englewood, New Jersey.
734, 736. Glaciated surface of trap at reservoir, Weehawken, New Jersey.
798, 799. Typical glaciated surface with scratches from the grounding of icebergs, shore of lake Ontario at Pillar Point, New York.
901. Glaciated surface, Bronx Park, New York city.
902. Glacial furrows across the foliation of the gneisses, Bronx park, New York city.
971. Glaciated scratches on shale near Fox gap, Monroe county, Pennsylvania.
972. Great glacial grove on table rock at Delaware water gap, Pennsylvania.
975. Glaciated boulder, Bangor, Pennsylvania.
979. Glacial striæ, south slope of Godfreys ridge, Monroe county, Pennsylvania.
1011. Glaciated boulder from moraine, base of Huntingdon mountain, near Jonestown, Columbia county, Pennsylvania.
1402. Striated limestone boulder from loess, Norway, Iowa.

*Glacial Topography

(See also Glacial Deposits and Glacial Lakes)

24. Country south of Malaspina glacier recently abandoned by ice.
32. Glaciated surface, Haenke island, Alaska.
70. Rounded limestone on Drake island.
177. Dome above Nevada falls, Yosemite valley, California.
178. Domes above Nevada falls, Yosemite National park, California.
185. Plateau north of Yosemite valley and canyon of Tenaya creek, from near Sentinel dome, in Yosemite park.
206. Glaciated rocks, southeastern slope of mount Shasta, California.
220. Gibbs canyon, from Williams butte, Mono valley, California.
221. Bloody canyon, south of Mono lake, California.
227. Tuolumne valley, California, showing upper limit of ancient glacier.
228. Glaciated country near mount Dana, California.

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* Only the more striking views are included.

234. Glaciated dome in Tuolumne valley, California.
275. View near headwaters of north fork of Big Pine creek, Sierra Nevada mountains, Inyo county, California.
284. Glaciated canyon north of lake Eleanor, Tuolumne county, California.
298. Glaciated granite, about 6 miles north of Hetch-hetchy valley, Tuolumne county, California.
299. Glaciated surfaces at Granite lake, Tuolumne county, California.
300. Glaciated knob of columnar hornblede andesite, 3 miles west of Silver peak, Alpine county, California.
301. Granite north of Charity valley, Alpine county, California.
302. Moraines north of Pleasant valley, Alpine county, California.
307. Glaciated granite, with fissures and lavas, from Charity valley, Alpine county, California.
310. Glaciated surface of basalt, western Canada.
320. Ice-pressed boulder pavement, Red Deer lake, Saskatchewan.
323. Laurentian gneiss, southern shore of Little Play, Green lake, Canada.
427. Longs peak, Colorado.
543, 544. Paha between Mount Vernon and Lisbon, Iowa.
548. Lingulate lobes of heavy loess near Iowan frontier, northwest of Princeton, Scott county, Iowa.
549. Kansan drift-sheet, showing slopes of larger ravines; south of Cedar river, Linn county, Iowa.
553. Kansan drift-sheet loess-mantled spatulate gullies, south of London, Cedar county, Iowa.
564. Kansan-loess topography, showing even sky line and spatulate valleys, Dixon, Scott county, Iowa.
588. Mount Desert Island ; looking southwest from Green mountain.
589. Eagle lake, Mount Desert island.
621. *Roche moutonnée*, Marblehead, Massachusetts.
720. Cathedral rock, with hills of typical *roche moutonnée* outline, North Conway, New Hampshire.
733, 734, 736. Palisade trap, New Jersey.
754. Till plain near Jeddo, Niagara county, New York.
760. Solitary gravel kame near Middleport, New York.
784, 785. Channel opened by Erian drainage while the ice-sheet occupied the Ontario basin, between Syracuse and Jamesville, New York.
786, 787. Channel opened by Erian drainage while the ice-sheet occupied the Ontario basin, near Marcellus, New York.
788. The Gulf. A channel opened by Erian drainage while the ice-sheet occupied the Ontario basin, west of Marcellus village, New York.
794, 795. Drumlins, south of Newark, New York.
796. Drumlin, 2 miles southwest of Jamesville, New York.
966. Kettle-holes in the moraine in Cherry valley, Monroe county, Pennsylvania.
967. The terminal moraine crossing Cherry valley, Monroe county, Pennsylvania.
968. Long ridge, terminal moraine on the Pocono plateau, Monroe county, Pennsylvania.
969. Moraine kettle and kames in Cherry valley, Monroe county, Pennsylvania.
970. Kames in Cherry valley, Monroe county, Pennsylvania.

973. The terminal moraine west of Coles creek, in Columbia county, Pennsylvania.
976. Terminal moraine near Saylorsburg, Monroe county, Pennsylvania.
980, 981. Terminal moraine near Bangor, Northampton county, Pennsylvania.
982. Moraine hummocks west of Bangor, Northampton county, Pennsylvania.
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1219. Cascade pass, Cascade range, Washington.
1240. Moraine at Carbon River glacier, mount Rainier, Washington.
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651, 652. Canton mine, Mesabi range, Minnesota.
653. A western Missouri coal mine.
654. Open cut and stopes at Pilot knob, Missouri.
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815. Interior of Dixon plumbago mine, near Hague, Warren county, New York.
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951. Compressed-air locomotive, Old Eagle mine.
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995–997. Old Wheatley lead mine, near Phœnixville, Pennsylvania.
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1012, 1024. Stripping at Hollywood colliery No. 1, Pennsylvania.
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1014. Pottsville deep shaft, Pennsylvania.
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1023. Culm and rock heaps at Shenandoah, Pennsylvania.
1117. Open cut in Father de Smet mine, Black hills, South Dakota.
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1119. Deadwood gulch, near Deadwood, Black hills, South Dakota.
1133. Iron mine in "gossan" of a pyrrhotite vein, Isabella mine, Ducktown, Tennessee.
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(Marked instances only)

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402. Vertical Red beds, Perry park, Colorado.
403-406. Garden of the Gods, Colorado.
410. Colorado City, Colorado; Triassic and Jurassic.
663, 664. Hogback of upturned Cambrian sandstone, Indian creek, west of Townsend, Montana.
672. Lower Paleozoic section, north fork of Dearborn river, Montana.
673. Carboniferous limestone cliff of mount Dearborn.
712. North end of Clayton valley, capped by basalt.
1099. Hogbacks of Dakota sandstone, Buffalo gap, Black hills, South Dakota.
1216. Silurian quartzite, Rathole mountain, valley of James river, Virginia.
1268. Paleozoic rocks southwest of Sheridan, Big Horn mountains, Wyoming.
1282. Jurassic rocks, Como (Aurora), Wyoming.

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453. Triassic sandstone from Portland, Connecticut.
1167. Recent mud cracks, Skin quarter, Virginia.

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1109. Jurassic sandstone near Buffalo gap, Black hills, South Dakota.
1080. Protoceras sandstone, Big Bad lands, South Dakota.
1189-1191. Natural bridge, Virginia.
1314. Rhyolite, Bridge creek, Yellowstone park, Wyoming.

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1168. Fragment of prismatic coke at Gayton, Virginia, at contact with vertical trap dike.
1169. An outcrop of columnar coke, north of Saunders slope, Gayton, Virginia.

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281. Canyon of fork of Mokelumne river, California.

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508. Oolite quarry, Steinsville, Indiana.
510. Hunter's quarry, Bloomington, Indiana.
511. Johnson's quarry, Bloomington, Indiana.
521. Gypsum quarry, Fort Dodge, Iowa.
532. Cedar Valley quarry, Iowa.
535. Champion quarry, Stone City, Iowa.
558. Bieler's quarry, Cedar valley, Iowa.
590. Granite quarry, Hallowell, Maine.
781. Quarry in Medina sandstone, Lockport, New York.

782. Quarry in Niagara limestone, Lockport, New York.
829. Trenton limestone, Glens Falls, New York.
833. Helderberg limestone at Howes cave, New York.
838, 839. Helderberg limestone, south Bethlehem, New York.
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848. Cement near Whiteport, New York.
952. Deshong quarry, near Chester, Pennsylvania.
953, 1027. Ward's quarry, near Chester, Pennsylvania.
954. Ohlinger Dam quarry, near Reading, Pennsylvania.
955, 956. Leiper's quarry, Delaware county, Pennsylvania.
960. Feldspar quarry, Delaware county, Pennsylvania.
961. Kaolin mine, Chester county, Pennsylvania.
962. Kaolin mine at Hockeshin, Delaware.
984. Lafayette soapstone quarry, Montgomery county, Pennsylvania.
993. Rausch's gravel quarry, Bethlehem, Pennsylvania.
994. Limestone quarry, Bethlehem, Pennsylvania.
1000, 1026. Avondale quarry, Delaware county, Pennsylvania.
1005. Potts' limestone quarry, below Morristown, Pennsylvania.
1006. Limestone quarry, Port Kennedy, Pennsylvania.
1029. Franklin slate quarry, Slatington, Pennsylvania.
1030. Slate quarry, Bangor, Pennsylvania.
1100. Grindstone quarry in Dakota sandstone, Edgemont, South Dakota.
1127. Marble quarry, Knoxville, Tennessee.
1151. Cambrian quartzite, Burlington, Vermont.
1155. Marble quarry, West Rutland, Vermont.

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424. Modern rainprints, natural size; dried mud from Great plains, Colorado.

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224. End of Obsidian flow, Mono craters, California.
225. Mono crater, California.
239. Lava-capped river bed of the ancient Sacramento near Delta, California.
240-252. Scene of a late volcanic eruption in northern California. Cinder cone, lava field, ash-covered slopes, lava dam, volcanic bombs and blocks.
355-357, 361. Costa Rica. Ira Zu volcano.
359, 360. Costa Rica. Crater lake of Poas volcano.
460-494. Hawaiian islands.
627. Section of lava flow, El Pedregal of Tialpam, near San Angelo, Mexico.

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948. Rocky ridge and East broad top coal basins, in Huntington county, Pennsylvania.
949. Bald Eagle mountain and Nittany valley, Pennsylvania.
950. Cornwall iron mines, Pennsylvania.

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327. Lower Helderberg rocks, Arisaig, Nova Scotia.
775, 779. Ripple-mark on Medina sandstone, Lockport, New York.
776. Flagstone at Elyria, Ohio.
777. Large ripple-mark in Medina sandstone, Niagara gorge, New York.
778, 780. Large ripple-mark in Medina sandstone, Lewiston, New York.
938, 939. Ripples on dunes, Biggs, Oregon.

RIVER FLATS AND FRESHET DEPOSITS

(See also River Terraces and Deltas)

20, 26. Yahtse river, Alaska.
99. Dyea, Alaska.
111. Mouth of Chettyna river, Alaska.
171. Shingle, Yosemite valley, California.
330. South Saskatchewan river, Northwest Territory.
353–354. Low tide in the basin of Minas, Nova Scotia.
394. Animas flood plain, Colorado.
494. Valley of Haualei, Sandwich Islands.
524. Flood plain of the Missouri, below Westfield, Iowa.
551. Valley of Cedar river, south of Mount Vernon, Iowa.
642. Lake Michigan near Glen Arbor, Michigan.
670. View down Yellowstone valley, Montana.
681. Platte river at Scotts bluff, Nebraska.
694. Platte river at Wyoming-Nebraska line.
710. Humboldt valley, Nevada.
767. Valley of Eighteen-mile creek, Niagara county, New York.
1141. Colorado river near Mount Bonnell, Texas.
1170. James river at Vinita, Virginia.
1171. James river near Cornwallis hill, Virginia.
1229. Columbia river, east of lake Chelan, Washington.
1296. Ox-bow bend, Hayden valley, Yellowstone park, Wyoming.

RIVER MEANDERS

(Marked examples only)

107. Klutena river at Devils elbow.
494. Valley of Haualei, Kauai.
710. Sediments of lake Lahontan, Humboldt valley, Nevada.
888. Ray brook, Adirondacks, New York.
1296. "Ox-bow" bend, Trout creek, Yellowstone National park, Wyoming.

RIVER TERRACES (OLD AND NEW)

(See also River Flats)

84. Stream terraces at end of Muir glacier.
107. Klutena river at Devils elbow.
456–459. Embankments of river Po, Italy.

495, 496. Terraces of Tertiary lake-beds on Lemhi river near Salmon City, Idaho.
935–937. Dunes, Biggs, Oregon.
1170. South bank of James river at Vinita, Virginia; flood plain in foreground.
1171. James river and Cornwallis hill.
1228. Columbia valley, Washington; terraces of Pleistocene age and high plateau of Miocene basalt.
1229. Columbia river, Washington, east of lake Chelan.
1230. Gravel terraces of stream origin in delta of Chelan river at its junction with the Columbia, Washington.
1232. Chelan falls, Columbia River, Washington; terrace 600 feet above the Columbia.
1239. Lake Chelan, Washington, and outlet; general view of the drift dam and the site of Chelan.

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623, 624. Cape Cod, Massachusetts.
644. Near Sleeping Bear bluff, eastern shore of lake Michigan.
645. South Manitou island, lake Michigan.
686, 687. Typical sand hills, north of Camp Clarke, Nebraska.
935–939. Dunes, Biggs, Oregon.
1231. East of lake Chelan, Washington.

SCHISTOSITY, CLEAVAGE, AND JOINTING

(See also Columnar Structure)

3. Near Kadiak, Alaska.
95. Dark limestone, with schistosity and quartz, Gens de Larg river, Alaska.
165, 166. Royal Arches, Yosemite valley, California.
176. Granite with forms of erosion, Conness Peak trail, Yosemite park, California.
180. Fractures in granite at base of Liberty cap, Yosemite park, California.
183. The Arches, Yosemite valley, California.
188. Exfoliating granite east of Royal Arch lake, Yosemite valley, California.
189, 190. Exfoliating granite on slope northwest of Grouse lake, Yosemite valley, California.
219. Joints in granite, mount Lyell, California.
254. Cambrian quartzites showing vertical cleavage of the strata, Soldiers canyon, White Mountain range, Inyo county, California.
255–257. Lower Cambrian quartzites, showing vertical cleavage in massive layers and interbedded thin layers without cleavage, Soldiers canyon, White Mountain range, Inyo county, California.
270. Granite on hill on north side of Deep Spring valley, Inyo county, California.
272, 273. Cambrian limestone and sandstone, Waucobi canyon, Inyo county, California.
288. Old andesite (porphyritic) tuffs west of Salmon lakes, Sierra county, California.
391. Table mountain, Golden, Colorado, showing unequal, horizontal tabular jointing in basalt wall.
393. Granite in Animas canyon, Colorado.

527. Quarry in Devonian limestone, showing two parallel joints. Near Iowa City, Johnson county, Iowa.
528. Columns of Saint Croix sandstone, Lane's farm, Iowa.
556. Leclaire limestone, illustrating breaking down of cliffs along joint planes Near Massillon, Iowa.
664. Hogback, formed by upturned Cambrian sandstone. West of Townsend, Montana.
769. Section of Niagara limestone, near La Salle, Niagara county, New York.
770. Section in cut of Erie railway, Niagara falls, New York.
782. Quarry face in Niagara limestone, Lockport, New York.
793. Grouped joints in Devonian shale, Watkins glen, New York.
805–807. Penrhyn slate quarry, Middle Granville, New York.
809. Cliffs in Topmans gulf, Jefferson county, New York.
954. Ohlinger Dam quarry, showing both dip and cleavage in Laurentian gneiss, near Reading, Pennsylvania.
957, 958. Quarries at Slatington, Pennsylvania.
1028. Slate quarry at Bangor, Pennsylvania.
1029. The Franklin slate quarry, Slatington, Pennsylvania.
1035. Quarry near Bellemont post-office, Lancaster county, Pennsylvania.
1041. Ohio river and bluff opposite Beaver, Pennsylvania.
1125. Palisades on Split Rock creek, South Dakota.
1220. Cascade pass, Cascade range, Washington; cliffs of hornblendic gneiss exhibiting vertical jointing.
1222. Basin peak, Cascade range, Washington.
1397. Gneiss, showing foliation, Massachusetts.

Shore Cliffs

(See also Lake Terraces and River Terraces)

25. Sitkagi bluffs at margin of Malaspina glacier.
317. Swampy island, lake Winnipeg, Manitoba.
321. Cedar lake, Saskatchewan, Northwest Territory.
322. Northwest shore of lake Winnipeg, Manitoba.
324. North side Deer island, lake Winnipeg.
329. The Ovens, Nova Scotia.
342. Conception Bay, Newfoundland.
358. Hicaron island, Pacific ocean.
598. Plum point, Calvert county, Maryland.
600. Wortons point, Kent county, Maryland.
605–609, 614. Head of Chesapeake bay, Maryland.
619. Long Island head, Boston harbor, Massachusetts.
622. Great Brewster islands, Boston harbor, Massachusetts.
628. Mackinaw island, Michigan.
629. Sea-cliff near Marquette, Michigan.
630. Au Train island, lake Superior, Michigan.
631, 633, 643. South Manitou island, Michigan.
632. Sleeping Bear point, lake Michigan, Michigan.
634. North Manitou island, lake Michigan, Michigan.

642. Lake Michigan near Glen Arbor, Michigan.
725. Palisades of the Hudson, New Jersey.
737. Griffin bay, lake Ontario, New York.
746. Limestone blocks, rounded by wave action, near Watertown, New York.
783. Lake Ontario at Wilson, New York.
878. Palisades of lake Champlain, New York.

SINK-HOLES

1278. Minnekahta limestone east of Cambria, Wyoming.
840. Helderberg limestone near Coxsackie, New York.

SPHEROIDAL STRUCTURE

392. North Table mountain near Golden, Colorado.
940. Volcanic rock, 1 mile east of Cascade locks, Oregon.

SPRINGS

(See also Geysers and Spring Deposits)

1096. Thermal springs at Cascade, South Dakota.
1309. Spring in Gallatin canyon, Wyoming.

SPRING DEPOSITS

217. Towers of tufa, shore of Mono lake, California.
364, 365. Calcareous tufa bank, Cement creek, Gunnison county, Colorado.
374. Iron spring near Ophir, Colorado.
689. Spring and its saline deposits from Pierre shale, Chadron, Nebraska.
708. Tufa domes, Lake Lahontan basin, Nevada.
1121. "Spearfish falls," Black hills, South Dakota.
1283, 1335. Minerva terrace, Mammoth hot springs, Yellowstone park, Wyoming.
1284, 1330. Paint pots near Fountain hotel, Yellowstone park, Wyoming.
1285–1287. Fountain geyser, Yellowstone park, Wyoming.
1288–1295. Angel terrace, Yellowstone park, Wyoming.
1317. Runway of Indigo spring, Yellowstone park.
1318. Algæ basins, Emerald spring, Upper Geyser basin, Yellowstone park.
1319. Spike geyser, Witch creek, Yellowstone park.
1320. Siliceous sinter from Coral spring, Yellowstone park.
1331. Beehive geyser, Yellowstone park.
1332. Lone Star geyser, Yellowstone park.
1333. Excelsior geyser, Yellowstone park.
1334. Fountain basin, Yellowstone park.
1336. Castle geyser, Yellowstone park.
1337. Upper Geyser basin, Yellowstone park.
1338. Upper Geyser basin; formation of siliceous sinter, Yellowstone park.
1339. Crater of the Castle geyser basin, Yellowstone park, Siliceous sinter.
1340. Crater of the Grotto geyser, Yellowstone park.
1341. Old Faithful in eruption, Yellowstone park.

1283, 1335, 1342, 1343. Mammoth hot springs, Yellowstone park.
1349. Cleopatra and Jupiter terraces, Mammoth hot springs, Yellowstone park.
1351. Pulpit terraces, Mammoth hot springs, Yellowstone park.

TEPEE BUTTES

413. Group north of Nepesta, Pueblo county, Colorado.
414. Two miles northeast of Boone, Colorado.
415. Exposed core of a Tepee butte north of Nepesta, Pueblo county, Colorado.
1279. Typical butte, due to limestone lense in shale, Weston county, Wyoming.

TUFACEOUS LAKE-BEDS

704, 707, 709, 711. Lake Lahontan, Nevada.

UNCONFORMITIES

(Near views only)

239. Lava-capped river-bed, near Delta, California.
294. Neocene gravels on Iowan sandstone, Amador county, California.
347. Gneiss and Trenton limestone, near Montmorenci falls, Canada.
409. Silurian sandstone on gneiss, etc., near Canyon City, Colorado.
450, 451. Triassic conglomerate on crystalline schist, near Southington, Connecticut.
505. Drift on limestone, Chicago drainage canal, Illinois.
542. Drift on Leclaire limestone, Scott county, Iowa.
552. Niagara on Hudson, Lyons, Iowa.
593, 594, 603. Columbia formation on crystalline rocks, Washington, D. C.
595. Lafayette formation on Chesapeake sands, Washington, D. C.
596. Chesapeake, Matawan, and Potomac formation, District of Columbia.
605–608. Columbia formation on Potomac formation, head of Chesapeake bay, Maryland.
611. Columbia and Potomac formations, Baltimore, Maryland.
612. Formation of gravel from vein quartz, Washington, D. C.
803. Calciferous sandrock on gneiss, Little falls, New York.
825. Potsdam sandstone on crystalline rock, Jessups landing, Saratoga county, New York.
826. Potsdam conglomerate on crystalline rock near Mosherville, New York.
830. Calciferous sand rock on crystalline schist, near Downing station, New York.
846. Champlain clay against Helderberg near Rondout, New York.
1067. Titanotherium beds on Pierre shales, Washington county, South Dakota.
1105. Jurassic sandstone on Red beds, south of Hot Springs, South Dakota.
1111. Cambrian sandstone on crystalline schist, Deadwood, South Dakota.
1136. Volcanic ash and chalk, Kountz series, Texas.
1148. Carboniferous and Permian, Hurricane cliff, south of Toquerville, Utah.

VEINS

126. Quartz gash veining in blue quartz schist bed rock on Tasnuna river, Alaska.
393. Granite cut by veins of quartz, feldspar, and biotite, coarse, in canyon of Animas river, Colorado.

626. Weathering of quartz vein near El Bote mine, Zacetecas, Mexico.
1158, 1159. Seams in limestone filled with calc-spar, Calciferous formation, Highgate springs, Vermont.
1222. View of Doubtful lake and slope of mountain, showing joint systems which are commonly mineralized, Basin peak, Cascade range, Washington.

WATERFALLS

1. Black creek, Alabama.
96. Gens de Lars rapids, Alaska.
181. Vernal falls, Yosemite valley, California.
236. Burney falls, Shasta county, California.
337–340. The Grand falls of Labrador.
343. Falls of Manuels brook, Conception bay, Newfoundland.
421. Typical water-pocket near Thatcher, Colorado.
460. Peepee falls near Hilo, Hawaiian islands.
462. Rainbow falls, Hawaii.
618. Great falls of the Potomac.
724. Falls of the Passaic, Paterson, New Jersey.
791. Post-Glacial canyon in Devonian shales, Watkins glen, New York.
792. Waterfall in Watkins glen, New York.
804. High falls of Genesee river at Rochester, New York.
812. Distant view of "High falls," at Trenton falls, New York.
817. Calciferous on East Canada creek, Herkimer county, New York.
818. Calciferous on East Canada creek, Herkimer county, New York.
821. Ravine in Utica shales behind Canajoharie, New York.
823. Principal falls of Trenton falls, New York, over Trenton limestone.
828, 885. Glens falls on Hudson river, New York.
832. Spencer falls, Trenton falls, New York, over Trenton limestone.
834. Indian ladder, Helderberg mountains, Albany county, New York.
849–851. High falls, Ulster county, New York.
855. Awosting falls, near lake Minnewaska, Ulster county, New York.
856. Honk falls, near Napanoch, Ulster county, New York.
871. Rainbow falls, Ausable chasm, New York.
886. Lower falls, Falls Creek gorge, Ithaca, New York.
892. Bog River falls, Adirondacks, New York.
906–911. Niagara falls.
1121. Spearfish falls, Black hills, South Dakota.
1156. Highgate falls, Vermont.
1188. Lace falls, Cedar creek, above Natural bridge, Virginia.
1245. Falls on Snoqualmie river, Washington.
1299. Waterfall over Cambrian limestones, Sheep creek, Teton range, Wyoming.
1308, 1313. Keplers cascade, Fire Hole river, Yellowstone park.
1310. Emerald Creek falls, Yellowstone park.
1311. Tower falls, Yellowstone park.
1312. Rustic falls, Glen lake, Yellowstone park.
1327. Fire Hole falls, Yellowstone park.
1329, 1346, 1348. Lower falls of Yellowstone river, Yellowstone park.

1338. Upper Geyser basin, Yellowstone park.
1344, 1347. Upper falls of the Yellowstone, Yellowstone park.

WEATHERING

(See also Schistosity, Cleavage, Jointing, and Wind Erosion)

176. Granite showing effect of cleavage fractures in producing forms of erosion, Conness Peak trail, Yosemite valley, California.
186. Rock basin, Yosemite valley, California.
187. Weathering of biotite-granite, ridge south of Morrison creek, a branch of the Tuolumne river, Yosemite valley, California.
226. Eolian erosion in rhyolite, Mono valley, California.
268, 269. Granite boulders resulting from disintegration of massive granite, Sierra Nevada, Inyo county, California.
271. Cherty layers in limestone, Inyo county, California.
283. Shattered granite crest of the Sierra Nevada, Tuolumne county, California.
289. Exfoliating granite on crest of Sierra Nevada, south of Raymond peak, California.
319. Dakota sandstone near an old lake Agassiz shore-line, Kettle hill, Swan lake, Manitoba.
362. Volcanic boulder drift, chief geologic feature of Central America.
371. Mount Sneffels, San Juan county, Colorado.
372. Characteristic cliff of fine-grained andesitic tuff, Bridal Veil basin, near Telluride, Colorado.
373. Characteristic cliffs and pinnacles of coarse-bedded andesitic breccia and tuff; South Lookout peak near Ophir, San Juan mountains, Colorado.
377. Typical cliffs of bedded breccias and tuffs, Vermilion peak, San Juan mountains, Colorado.
392. Spherical sundering in basalt, northern Table mountain, Golden, Colorado.
398. Cliffs on San Juan tuff, north of Full Moon gulch, Colorado.
509. Weathering of oolitic limestone near Herodsburg, Indiana.
537. Saint Peter sandstone, Iowa.
540. Niagara limestone stairway at "Devils Backbone," Delaware county, Iowa.
542. Leclaire limestone below drift, Scott county, Iowa.
666–669. Carboniferous sandstones 8 miles south of Livingston, Montana.
677. Eroded sandstones, Teton county, Montana.
713, 714. Cones formed by unequal erosion of rhyolite-tuff in foothills of Palmetto mountains, Nevada.
771, 772. Niagara limestone, joint face exposed in quarrying southwest of Middleport, New York.
810. Decay of upper semi-crystalline beds of Trenton limestone above Trenton falls, New York.
913. Decomposed trap rock at Wadesborough, North Carolina.
985–987. Trap boulders, French creek falls, Pennsylvania.
991. Gneiss peak, Lower Bethel township, Delaware county, Pennsylvania.
1040. Field of gabbro boulders, southeastern Pennsylvania.
1041. Concentric weathering in bank of Ohio river, Pennsylvania.
1097–1098, 1107–1108. Granite needles near Harney peak, South Dakota.

1102. Beecher rocks, erosion in pegmatite, south of Custer, South Dakota.
1105. Jurassic sandstone on Red beds, near Hot Springs, Black hills, South Dakota.
1138. Decomposition of tuff and stalagmites, Pilot Knob series, Texas.
1139. Bored limestone above tufa, Pilot Knob series, Texas.
1144. Rain erosion, Travis Peak series, Texas.
1208. Fields of residual clay near Natural bridge, Virginia.
1269, 1270. Cliffs near Bald mountain, Big Horn mountains, Wyoming.

Wind Erosion

(See also Bad Lands, Weathering, and Castellated Topography)

226. Rhyolite, Mono valley, California.
700. Gering formation, Banner county, Nebraska.

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
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PROCEEDINGS OF THE FOURTEENTH ANNUAL MEETING, HELD AT ROCHESTER, NEW YORK, DECEMBER 31, 1901, AND JANUARY 1 AND 2, 1902, INCLUDING PROCEEDINGS OF THIRD ANNUAL MEETING OF THE CORDILLERAN SECTION, HELD AT SAN FRANCISCO, DECEMBER 30 AND 31, 1901

HERMAN LE ROY FAIRCHILD, *Secretary*

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Session of Tuesday, December 31

The Fourteenth Winter Meeting of the Society was called to order at 10.15 o'clock a. m. by First Vice-President N. H. Winchell, President Walcott having been detained on account of delay in arrival of railroad trains, in the geological lecture-room, Sibley hall, University of Rochester, where all the sessions were held, except that of Tuesday evening. In anticipation of the arrival of the President, the customary formalities of welcome to the Society were deferred to a later hour (see page 517).

Announcements were made regarding certain details of the meeting, and of the dinner; also of an invitation from Ward's Natural Science establishment.

The report of the Council, including reports of the officers, was submitted by the Secretary, in print, without reading, as follows:

REPORT OF THE COUNCIL

To the Geological Society of America,
in Fourteenth Annual Meeting Assembled:

The Council has held its stated meetings during the past year in conjunction with the meetings of the Society, at Albany and Denver. The affairs of the Society continue in their normal state of prosperity, and outside of the matters covered by the reports of the Officers, which are included herein, there is little requiring special mention. The matter of investment of funds authorized by the Council is described in the Treasurer's report. The subject of Summer Meetings is discussed in the Secretary's report and the suggestions are approved. The legislation relating to the Cordilleran Section has been completed and is here placed on record as follows:

Cordilleran Section

At Washington, December 28, 1899, the Society, upon petition from Fellows residing on the Pacific coast and accompanied by recommendation of the Council, authorized the formation of a Cordilleran Section, and empowered the Council to make rules for the government of the Section. Thus far the matter is on record in the Bulletin, volume 11, page 587.

In pursuance of its duty the Council, on December 29, 1899, appointed a committee to formulate rules for the guidance of the Cordilleran Section and to report to the Council. This committee was named as follows: Messrs Bailey Willis, J. J. Stevenson, J. C. Branner, W. M. Davis, and the Secretary. It was impracticable for the committee to meet and the work was done by correspondence, Mr Bailey Willis acting as Chairman. A unanimous report was submitted in May and was adopted by the Council at Denver, August 26, 1901. Following are the rules as adopted:

RULES OF THE CORDILLERAN SECTION

(Adopted by the Council August 26, 1901)

1. *Officers.*—The officers of the Cordilleran Section shall be a Chairman and a Secretary. The latter shall also perform the duties of an accounting officer with reference to the expenses of meetings.

The officers of the Section shall be resident within the geographical limits of the Section. A President or Vice-President of the Society shall be, *ex officio*, Chairman of the Section whenever present at a meeting.

2. *Geographical limits.*—For purposes of scientific fellowship and discussion the limits of the Section shall correspond with the limits of the general Society, and the meetings of the Section shall be open to all Fellows of the Society for presentation of papers, either in person or by proxy. For purposes of administration the membership of the Section shall be limited to those Fellows residing west of the 104th meridian.

3. *Membership.*—No person not a member of the Society may become a member of the Section. Members may invite contributions to the discussions at their meetings under the same rules as those applied to meetings of the Society.

4. *Date of meetings.*—The meetings of the Section may be held at any time, subject to approval by the Council of the Society (article 4 of Constitution). All notices and programs of meetings shall be sent to all Fellows of the Society.

5. *Expenses.*—The expenses of the Section, so far as they shall be paid from the general fund of the Society, shall be limited to the ordinary economical expenses of the meetings.

6. *Publications.*—All papers presented to the Section shall be available for publication in the Bulletin of the Geological Society of America under the rules governing publication by the Society.

Professor A. C. Lawson, a member of the Council and Secretary of the Cordilleran Section, stated that the Section desired to hold annual meetings in December, and the Council gave approval by formal vote.

SECRETARY'S REPORT

To the Council of the Geological Society of America:

Meetings.—The records of the Thirteenth Annual Meeting, held in Albany, December, 1900, and the Thirteenth Summer Meeting, Denver, August, 1901, are printed in the Bulletin. According to custom, the Summer Meeting occupied one day of the time of Section E, American Association for the Advancement of Science.

Excursions.—Attention is again called to the subject of excursions and field study by Professor Van Hise in his account of the Colorado excursion (Bull., vol. 13, proceedings of Denver meeting). There can be no doubt of the value of well-planned excursions. They might entirely replace the summer meetings. Indeed, if the American Association should change the time of its meetings to the winter, the summer meetings of our Society, which have always been small, should be changed to excursions or field meetings.

In the present good condition of the finances the Society can afford to encourage excursions by paying moderate expenses of conductors and for printing of circulars and programs. The Council might invite the Fellows of the Society to submit schemes for excursions in their special fields. From these plans the Council could from year to year sanction those which seemed most desirable. Various reasons would enter into the matter of choice, which might involve the sequence or succession from year to year. Some of the excursions might be open to teachers and students of geology and physiography, while others should be restricted to the Fellows of the Society.

Membership.—Since the last report 5 Fellows have died—Edward W. Claypole, George M. Dawson, R. D. Lacoe, Joseph Le Conte, Theo. G. White. The 8 candidates elected at the summer meeting all qualified. Three names have been erased from the list for non-payment of dues and three by resignation,* making the present enrollment 245. Five Fellows are delinquent for two years. Three nominations are before the Society and several are before the Council.

Distribution of Bulletin.—Since the last report the closing brochures of volume 11 and the complete copies of the volume have been distributed. The brochures of volume 12 have also been sent, and before this report is read it is expected that volume 12 will have been entirely distributed, with probably the first brochures of volume 13.

During the year 1901 the irregular distribution of the Bulletin has been as follows: Complete volumes sold to Fellows, 21; to the public, 26. Three copies of volume 11 have been sent to Fellows on payment of back dues, 2 copies have been donated, and 3 have been bound for office use. Of brochures, 91 have been sent to fill deficiencies, 18 have been sold to Fellows, and 13 to the public; 6 have been donated. The sales appear in the table of Bulletin receipts later in this report.

Up to this time the Secretary has honored claims for deficiencies even in the early volumes. This practice should be discontinued, and the

---

* By oversight the names of the three Fellows resigned were not omitted from the last printed list (Bull., vol. 12, pp. 514-522).

Council should fix a time limit, beyond which claims for non-receipt of brochures will not be recognized.

Bulletin sales.—The following table shows the income from sale of the Bulletin during the official year:

Receipts from Sale of Bulletin, December 1, 1900, to December 1, 1901

	Complete volumes.			Brochures.			Grand total.
	Public.	Fellows.	Total.	Public.	Fellows.	Total.	
Volume 1	....	$13 50	$13 50	......	$2 20	$2 20	$15 70
Volume 2	....	13 50	13 50	$3 60	2 10	5 70	19 20
Volume 3	....	8 00	8 00	25	10	35	8 35
Volume 4	....	7 00	7 00	....	....	....	7 00
Volume 5 ..	$5 00	8 00	13 00	10	....	10	13 10
Volume 6	5 00	4 00	9 00	....	....	....	9 00
Volume 7	....	4 00	4 00	60	70	1 30	5 30
Volume 8 ...	....	4 00	4 00	....	....	.....	4 00
Volume 9 ...	10 00	4 00	14 00	3 10	60	3 70	17 70
Volume 10	35 00	4 00	39 00	2 50	30	2 80	41 80
Volume 11	300 00	13 50	313 50	......	1 00	1 00	314 50
Volume 12 ...	215 00	....	215 00	1 40	....	1 40	216 40
Volume 13 ...	20 00	....	20 00	....	....	....	20 00
	$590 00	$83 50	$673 50	$11 55	$7 00	$18 55	$692 05
Index.........	112 50	....	112 50	....	....	....	112 50
	$702 50	$83 50	$786 00	$11 55	$7 00	$18 55	$804 55

Receipts for the fiscal year..............................	$804 55
Previous receipts, to November 30, 1900..................	5,240 01
Total receipts to date....................................	$6,044 56
Charged and uncollected	257 25
Total Bulletin sales to date	$6,301 81

The large item for "uncollected" in the above table is due to the fact that bills have recently been sent in advance for the complete copies of volume 12 to subscribers.

Exchanges.—By a vote of the Council at the Albany Meeting three addresses were added to the list of exchanges: Danmarks Geologiske Undersogelse, Copenhagen; Instituto Geologico de Mexico; Carte Geologique du France, Paris. The Exchange list now includes 87 addresses.

Expenses.—The following table shows the cost of administration from the Secretary's office for the past official year:

EXPENDITURE OF SECRETARY'S OFFICE FOR THE FISCAL YEAR ENDING NOVEMBER 30, 1901.

Account of Administration

Postage and telegrams	$13 52	
Expressage	1 07	
Printing (including stationery and records)	86 98	
Meetings (not included in printing)	32 65	
Binding volumes for officers	6 00	
Total		$140 22

Account of Bulletin

Postage and telegrams	$82 43	
Expressage and freight	79 10	
Wrapping material	50	
Collection of checks	6 55	
Total		$168 58
Total expenses for the year		$308 80

Respectfully submitted.

H. L. FAIRCHILD,
Secretary.

ROCHESTER, N. Y., *December 20, 1901.*

TREASURER'S REPORT

To the Council of the Geological Society of America:

In submitting the annual financial statement the Treasurer herewith adds a few items of general interest.

During the year 3 Fellows have been dropped from the roll for non-payment of dues, 5 are delinquent for two years, 25 have not yet paid for the present year, while 7—W. S. Bayley, J. E. Spurr, H. B. Kummel, W. J. Sutton, A. N. Winchell, H. S. Washington, and F. C. Schrader—have commuted for life, thus increasing to 53 the number of Fellows who have placed their membership beyond any future contingency.

The 5 per cent bonds of the Cosmos Club of Washington, D. C., which the Society held to the amount of $1,700, were redeemed during the year and our permanent investment decreased to that extent. Under authority of the Council the President and Treasurer invested $1,000 in the stock of the Iowa Apartment House Company of Washington, D. C., which is confidently expected to yield a minimum return of 6 per cent, or about double the rate of interest now possible to realize from the purchase of any first-class bonds. The Treasurer would advise additional investments in the stock of this company if it can be obtained, since its management is both safe and conservative, and property of this kind

Statement of Receipts and Expenditures.

RECEIPTS.

Balance in the treasury November 30, 1900			$2,877 45
Fellowship fees 1899 (5)	$50 00		
" " 1900 (42)	420 00		
" " 1901 (163)	1,630 00		
" " 1902 (1)	10 00		
		$2,110 00	
Initiation fees (8)		80 00	
Life commutation fees (7)		700 00	
Interest on investments:			
Tioga Township, Kansas, bonds	$70 00		
Cosmos Club bonds	62 08		
Tunnelton, Kingwood and Fairchance Railroad bonds	18 00		
Texas Pacific Railroad bonds	100 00		
Iowa Apartment House Co. bonds	32 55		
On deposits in Security Trust Co.	100 61		
		383 24	
Investments repaid		1,700 00	
Sales of publications		804 55	
			5,777 79
Total amount of receipts			8,655 24

Total amount of receipts brought forward				$8,655 24

EXPENDITURES.

Administration, library, and distribution of Bulletin—				
Secretary's office:				
Administration	$178 32			
Distribution of Bulletin	222 11			
Allowance (for ordinary expenses)	500 00			
		$900 43		
Treasurer's office		24 20		
Librarian's office		11 05		
			$935 68	
Publication of Bulletin:				
Printing		$2,454 44		
Engraving		414 80		
Editorial expenses (including allowance for personal and office expenses)		250 00		
			3,119 24	
Investments:				
Ten shares of stock in Iowa Apartment House Co.			1,000 00	
Total amount of expenditures				$5,054 92
Balance in treasury November 30, 1901				$3,600 32

(apartment houses) in a city like Washington is sure to enhance in value, thus yielding an increasing rate of interest instead of a diminishing one.

In consequence of this Cosmos Club bond redemption the invested fund has decreased $700 since the last statement and now amounts to only $4,300, which sum represents 43 life commutation fees. This leaves 10 life commutations, or $1,000, immediately available from the treasury for permanent investment in the publication fund, according to the Constitution.

The Society continues to realize 4 per cent on monthly balances from the Security Trust Company of Rochester, New York, where all surplus moneys are kept, the receipts from this source during the year having amounted to $100.61, and the "interest" items from all sources foot up $383.24, a very snug sum considering the general reduction of interest rates that has taken place in recent years on all classes of good securities.

In spite of the extra expenditure of $501.75 for printing the special index of the first 10 volumes, the total balance for the year is $3,600.32, from which, after deducting the $1,000 previously referred to as belonging to the life commutation or publication fund, we have left $2,600.32 available for general purposes. The Treasurer would suggest that at least $1,000 of this, making $2,000 in all, be invested on account of the publication fund, thus increasing it to $6,300, and providing for the additional life commutation fees that are soon sure to be paid by the wise forethought of both new and old Fellows.

The detailed financial statement for the year with all known bills settled to December 1st, including the entire cost of volume 12, is on the preceding page.

Respectfully submitted.

I. C. White,
Treasurer.

Morgantown, West Va., *December 20, 1901.*

Editor's Report

To the Council of the Geological Society of America:

Volume 12 was completed November 27, 1901, by the issuing on that date of the proceedings brochure of the Albany meeting. It forms a book of 538 pages, with xii pages of preliminary matter, and is illustrated with 45 half-tone plates and 28 line cuts. It is slightly below the average of the first ten volumes in pages, but is nearly double in plate illustrations. This reflects the Society's generous policy in this direction and indicates the appreciation by the members of the facilities afforded. While the number of plates in volume 12 are less than those in volume 11, they cost more, owing to the necessary employment of lithography.

Reference to the table below will show that in cost volume 12 compares favorably with the average volume, but is a trifle more than volume 11 in cost per page, being more than one hundred pages smaller and with increased cost of illustrations.

	Average. Vols. 1–10.	Vol. 11.	Vol. 12.
	pp. 544. pls. 26.	pp. 651. pls. 58.	pp. 538. pls. 45.
Letter-press	$1,465 14	$1,815 56	$1,445 73
Illustrations	290 40	373 68	414 80
	$1,755 54	$2,189 24	$1,860 53
Average per page	$3 23	$3 36	$3 45

Exact classification of subject-matter has not been attempted, but the following comparative table presents a reasonably correct analysis of the contents of volumes 7 to 12, inclusive:

Divisions.	*Vol. 7. Pages.*	*Vol. 8. Pages.*	*Vol. 9. Pages.*	*Vol. 10. Pages.*	*Vol. 11. Pages.*	*Vol. 12. Pages.*
Areal geology	38	34	2	35	65	199
Dynamic geology	3	24	85	24	110	23
Economic geology	4	14	16	28	7	5
Glacial geology	105	98	138	96	21	55
Historical	..	..	..	16	46	..
Memoirs of deceased members	28	8	12	27	60	2
Official matter	56	69	54	72	59	58
Paleontology	123	58	64	68	188	5
Petrology	40	43	44	59	54	24
Physiographic geology	53	5	..	37	10	53
Relation of geology to pedagogy	12	..	..	..	..	..
Rock decomposition	74	26	17	9	..	16
Stratigraphic geology	21	67	28	62	31	98
Terminology	1	..	..	1	..	..
Total	558	446	460	534	651	538

The " Index to Volumes 1 to 10 " was issued on December 31, 1900, at a cost of $501.75. It makes a volume of 209 pages, and is uniform in every respect with the other brochures of the Society. It is chiefly a compilation of the indexes to the individual volumes, but many new titles have been added. The work of combining and adjusting the ten indexes and preparing new material was done almost entirely by Mr and Mrs George Wood, who are experts in indexing through long experience in the U. S. Geological Survey. To them is due in largest measure the credit for whatever merit the index possesses.

The present Editor is responsible for indexing seven of the ten volumes, but the first three of the series were indexed by Mr W J McGee, whose excellent standard was followed both in the individual volumes and in making the compilation.

All the material handed the Editor for publication in volume 13 is in the printer's hands and proof is being read. It will probably make some 75 pages.

Members are earnestly urged to send the manuscripts read or presented at the winter meeting as speedily as possible after its sessions are ended. The chief source of delay in closing the volume at the end of the year is inability to get the proof quickly to and from members scattered in their various summer and autumn fields of work.

Respectfully submitted.

JOSEPH STANLEY-BROWN,
WASHINGTON, D. C., *December 14, 1901.* *Editor.*

LIBRARIAN'S REPORT

To the Council of the Geological Society of America:

The list of accessions to the Library up to June, 1901, was compiled and forwarded in June and appears in the final brochure of volume 12 of the Bulletin, pages 503–512.

At the present writing the library comprises over 2000 numbers. Of these, some 500 represent pamphlets and other scattering material, while the remainder is nearly all received from our exchanges, now numbering 87, and consists either of serial publications or official reports. The majority of these come serially and unbound, and are bound at the expense of the Case Library. One hundred and fifty volumes have been bound during the year ending in June, and 160 more are now at the bindery. Three years ago the binding was sadly in arrears, but this has been made up, and in future merely the annual increase, from 75 to 100 volumes, will require binding.

At this writing the Case Library is moving from its old quarters to new ones. These latter are rented and comprise the entire eighth floor of a new and modern fireproof building. The library will be better and more spaciously housed than formerly, and will in its new quarters hardly require the carrying of any fire insurance.

There has not been a single call for books during the year from members of the Society not residing in Cleveland ; yet it would seem that there should certainly be a use for the library on the part of the members who live away from the large centers, with their great libraries, as a considerable number do. The yearly published lists of accessions show what societies are on the exchange list, and their publications for the past eleven years are on the library shelves and are subject to the call of any member of the Society, under the regulations laid down by the Council. With our widely scattered membership, the library may not be of great value to the Society at large, but its use should not be limited to the members residing in Cleveland.

The expenses of the Librarian's office during the year ending December 1, 1901, are as follows:

To postage	$0 97
express charges	1 83
envelopes and printing	2 65
insurance	5 60
Total	$11 05

Respectfully submitted.

H. P. Cushing,
Librarian.

Cleveland, Ohio, *December 1, 1901.*

On motion of the Secretary, it was voted to defer consideration of the Council report until the following day.

As the Auditing Committee to examine the accounts of the Treasurer, the Society elected Richard E. Dodge and Edmund O. Hovey.

ELECTION OF OFFICERS

The result of the balloting for officers for 1902, as canvassed by the Council, was announced and the officers declared elected as follows:

President:

N. H. Winchell, Minneapolis, Minn.

First Vice-President:

S. F. Emmons, Washington, D. C.

Second Vice-President:

J. C. Branner, Stanford University, Cal.

Secretary:

H. L. Fairchild, Rochester, N. Y.

Treasurer:

I. C. White, Morgantown, W. Va.

Editor:

J. Stanley-Brown, Washington, D. C.

Librarian:

H. P. Cushing, Cleveland, O.

Councillors:

C. W. Hayes, Washington, D. C.
J. P. Iddings, Chicago, Ill.

ELECTION OF FELLOWS

The result of the balloting for Fellows, as canvassed by the Council, was announced, and the following persons were declared elected Fellows of the Society:

Ermine Cowles Case, A. B., A. M. (Kansas State University, 1893), M. S. (Cornell University, 1895), Ph. D. (University of Chicago, 1896). Instructor in State Normal School, Milwaukee, Wis.

Arthur Gray Leonard, A. B., A. M. (Oberlin), Ph. D. (Johns Hopkins University), Des Moines, Iowa. Assistant State Geologist, Iowa Geological Survey.

Charles Hyde Warren, Ph. B. (Yale, 1896), Ph. D. (Yale, 1899), Boston, Mass. Instructor in Geology, Massachusetts Institute of Technology.

The following memorials of deceased Fellows were read:

MEMOIR OF EDWARD WALLER CLAYPOLE*

BY THEO. B. COMSTOCK

Edward Waller Claypole, born at Ross, Herefordshire, England, June 1, 1835; geologist of world-wide fame and teacher of geology of remarkable personality and effectiveness; an original fellow of the Geological Society of America; member and ofttimes president of numerous other organizations for the promotion of research, needs no eulogium from one privileged to greet him as monitor, friend, and fellow-worker. The impress of his severely conscientious labors, the importance of his contributions to geologic literature, his unswerving devotion in the cause of its propagation, have left indelible traces on the records of American geology for thirty years now past. Many of my readers are better fitted to tell the story, but none could attempt it with greater willingness or with more reason to perform the task as a token of esteem and affection.

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*The memoir was not read at the meeting, but is here inserted in its place, as on the printed program.

Doctor Claypole died at Long Beach, California, one of the coast resorts near Los Angeles, August 17, 1901. He had moved to Pasadena, California, in 1898, on account of the impaired health of Mrs Claypole, and was there busily engaged as a professor in Throop Polytechnic Institute. Although an obscure, but serious and painful ailment, apparently affecting chiefly the left hand, had caused him to rest under physician's orders, only the most intimate friends had any fears of fatal results, and these were not anticipating an early termination of his life. The worst contemplation was the possibility of retirement from active pursuit of his regular routine. While rising from bed on the morning of August 16, he suddenly became unconscious and remained thus until his death, at 11 p. m. of the 17th. The immediate cause was cerebral hemorrhage. His devoted wife survived him but a few weeks, dying October 6, 1901, at Pasadena. The remains of both were cremated, in accordance with their own expressed wishes.

The accompanying bibliography affords convincing evidence of the breadth of mental grasp of this man and his inability to overlook the simplest fact presented to him in contemplation of nature. But we must here confine our attention strictly to the geologic work on which his record was largely made. Contemporary estimates are not always reliable in such cases, but there will be no question of the importance of Doctor Claypole's investigations and their bearing upon the progress of this science during the last quarter of the nineteenth century. His papers were models of simple, straightforward expression, and stand as a marked example of what should be sought in scientific publications. He attracted attention not by his controversial literature, although few were better equipped than he for that class of work, but his papers nearly always provided the last word in argument, because he never came before the public until all his material had been thoroughly threshed and freed from chaff. It is this characteristic of careful pruning and rigid self-restraint which makes his writings of permanent worth. One may take at random from the list any title whatever, and if the date of its publication be noted carefully, investigation will demonstrate that it appeared many months, usually several years, after his work upon the subject began. Many able geologists are best known to their contemporaries by their environment at the time of their published work. It was not thus with Claypole. His periods of residence in given localities were collective, formative epochs, in which he gathered facts laboriously and digested them well; but he announced the results usually long afterward and frequently after removal from the scene of his studies.

To him the universe presented positive evidence of "the constancy and inevitability of natural law—its unswerving constancy, its inevitable certainty"—and the object of his investigations was never restricted to a narrow field, but he modestly and patiently toiled to seek and record truth in whatever aspect it came before him. Hence his record, partly also from the enforced conditions of his profession of teacher, was not limited to one particular line of investigation, even within the bounds of geology.

He began with the study of broad problems of areal physical geology, along lines and in fields made classic by his inspirer, the great Lyell. His first known publications dealt with evidences of land "Subsidence in the southwest counties of England during the present period." These ought to be read by every young student, as texts to go along with their Lyell and Geikie, Dana and Le Conte. These papers, and one on the Carboniferous system in a part of Midlothian, are a foretaste of what might have been his career had not misfortune, in the guise of urgent need and cruel persecution, sent him to America in 1872.

Naturally, at that period, his attention was forcibly drawn to studies of glacial phenomena, and his contributions to this department were material and frequent for many years. Upon cognate subjects, his only really controversial work was done. It would have been impossible then to contribute anything novel to the discussion without drawing fire from one or other quarter, and his views were not always greedily accepted by the contending factions. Even now it may be early to seek a final verdict, for too many able contestants survive and make valued additions to our knowledge of this great subject; but none will dispute the vigor of Claypole's logic, the earnestness of his purpose, or the worth of his contributions. His name would live for these alone, albeit they are but fragments of his vital productions.

With fuller recognition and better opportunities for him at this juncture, undoubtedly American glacial literature would have been enriched beyond its actual marvelous development; for there is a ring of zeal and acumen in certain of his papers which carry weight and hint of no ordinary power of observation and ratiocination. Geology has lost in this direction by its gain in other fields into which circumstances turned his energies.

Fugitive papers (1877–'79) on migration of plants and animals probably grew out of his studies of the Drift. They are strikingly valuable and deserve wider circulation than was given them.

Upon the Second Geological Survey of Pennsylvania, under Lesley, Doctor Claypole touched familiar ground in that hazy stratigraphic zone extending from Silurian to Carboniferous, which has puzzled and nonplussed more geologists than any other section. The publication of reports, as then customary, by volumes covering political areas, has partly obscured the glory of Claypole's work, although Doctor Lesley frankly credited him with it in his introductory remarks.

The significance of these determinations, as measured by the work involved, may lose force in distant perspective, but his fellow-workers can understand what it meant in those days to get the facts, and some can rightly estimate the value of the deductions and their intimate bearing upon their own labors in related fields. It was by these discoveries that a notable controversy was afterward settled and the valued work of a living authority rendered possible and invaluable. The results, epitomized, of Claypole's work in Perry county, Pennsylvania, were:

1. The identifying of No. V (First Geological Survey of Pennsylvania) as Clinton and Onondaga.
2. Demonstration of the absence of hitherto assigned Niagara and Corniferous.
3. Allotment of previously assigned Corniferous to Marcellus.
4. Definition of Upper Hamilton, Genesee, and Portage.
5. Discovery of Chemung and Catskill fauna extending high up into so-called Catskill.
6. Tracing of Kingsmill sandstone in all Catskill outcrops.

The finding of fish remains in Silurian rocks was an epoch-making discovery in itself, but the presentation of the facts and the detailed and painstaking studies given the fragments by Doctor Claypole were far more worthy of commendation. He continued to develop the subject long after retiring from the survey, and these contributions are among his best. The drawings were made by himself, and most of them are remarkable for their accuracy and clearness. Later, in Ohio, he bestowed much attention upon the Placoderms of the Devonian, publishing many papers on the anatomy of Cladodonts and their stratigraphic range.

In later years he wrote more of philosophic character, for which his long life of preparation and rumination had thoroughly equipped him. His paleontologic studies continued, and he won the Walker Prize as late as 1895, for his essay on "Devonian formation of the Ohio basin," an admirable review which, unfortunately, has never been published. He also continued his glacial studies when so placed as to have material at hand, and he was still hard at work garnering new facts from the Sierras of California when the end came. Shortly before his death he read a valuable paper bearing upon these researches before the Cordilleran Section of the Geological Society of America.

To those privileged to know him well, Doctor Claypole was the embodiment of simple, faithful, modest worth, exerting an influence, like all pure things, as if unconscious of any merit, yet impressing all with a sense of honor, strength and energy, and leading to nobler efforts by his example. His one aim, ambition and the fruition thereof, were always truth at any cost. This spirit breathes and lives in his written works. They are commended to all young students of nature.

CHRONOLOGY

1835. Born at Ross, Herefordshire, England, June 1.
1852. Began teaching at Abingdon, Berkshire, England.
1854. Matriculated at the University of London.
1862. Received the degree B. A. from the University of London.
1864. Received the degree B. Sc. from the University of London.
1865. Married Jane Trotter, of Coleford, Gloucestershire, England.
1866. Appointed tutor in classics and mathematics at Stokescroft College, Bristol, England.
1872. Resigned position in Bristol; came to America after death of his wife.
1873. Appointed professor of natural history at Antioch College, Yellow Springs, Ohio.
1879. Married Katharine Benedicta Trotter, cousin of his first wife.
1881. Left Antioch; appointed on staff of Second Geological Survey of Pennsylvania.
1883. Appointed professor of natural science in Buchtel College, Akron, Ohio.
1888. Received the degree D. Sc. from the University of London. Became one of the founders and editors of the American Geologist.
1898. Appointed professor of geology and biology at Throop Polytechnic Institute, Pasadena, California.
1901. Died at Long Beach, California, August 17.

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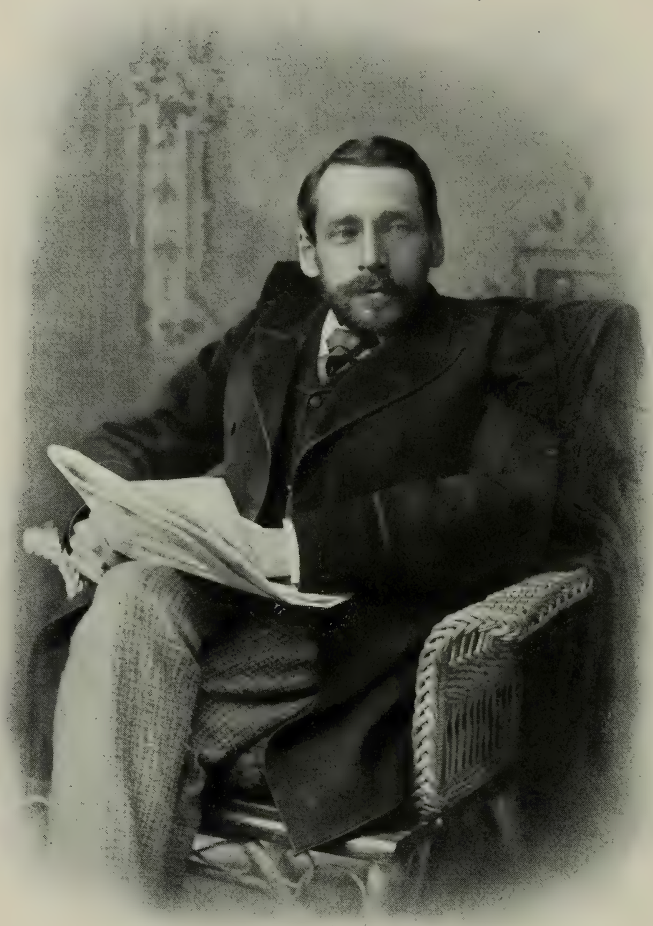

Yours truly

George M. Dawson

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MEMOIR OF GEORGE M. DAWSON

BY FRANK D. ADAMS

It was but two years since—at the Washington meeting—that we deplored the loss of one of our most distinguished Fellows and a former President of our Society, who had passed away at a ripe old age, Sir William Dawson. Today we have to record the death of his gifted son, also one of our past Presidents, and the latest, who was cut off suddenly in the prime of life and in the midst of what promised to be a long and useful career.

George Mercer Dawson was the second son of the late Sir William Dawson, and was born at Pictou, Nova Scotia, on August 1, 1849. In 1855 his father, who had for some years been acting as Superintendent of Education in Nova Scotia, received the appointment of Principal of McGill University, Montreal, and with his family took up his residence there. At the age of ten Dawson entered the Montreal high school, where he remained for one year, taking a high place among the boys of his class. There were, however, at that time, near what is now the center of the city of Montreal, a number of ponds on which the boys from the High School used to go rafting at lunch hour. On one of these occasions he received a drenching, and remaining in his damp clothes through the afternoon received a chill, which led to spinal trouble, resulting in years of suffering and final deformity. He consequently left school and his education, until he was old enough to enter college, was carried on chiefly under private tutors. In this way, while not neglecting the ordinary subjects of a school curriculum, he was allowed to follow out lines of study in which he found a particular interest and learned many things which were later of the greatest value to him. One who knew him well at that time says:

> "He seemed to absorb knowledge rather than to study, and every new fact or idea acquired was at once put into its place and proper relations in his orderly mind. He was always cheerful, amusing, and popular, other boys flocking round him and invariably submitting to his unconscious leadership."

At the age of eighteen, having recovered his health, he entered McGill University, where he studied during the session of 1868–'69, and in the following year went to London and entered the Royal School of Mines. His passage to England was made in a sailing ship for the benefit of the longer voyage, and on the way over he amused himself by studying navigation under the captain. Years later, when he chartered a schooner in order to make an examination of the Queen Charlotte islands, the captain of the schooner proving to be unsatisfactory was dismissed and Dawson navigated the vessel himself during the remainder of the trip and this on a deeply indented and dangerous coast, of which at that time no chart existed.

At the Royal School of Mines he took the full course of study, extending over three years, and graduated as an Associate. At the end of his second year he received the Duke of Cornwall's scholarship, given by the Prince of Wales, and on graduation stood first in his class, obtaining the Edward Forbes medal and prize in paleontology and natural history and the Murchison medal in geology. While at the Royal School of Mines he paid especial attention to the study of geology and paleontology, under Ramsay, Huxley, and Etheridge, and also devoted much time to the study of chemistry and metallurgy, in the laboratories of Frankland and Percy. Even in his holidays he was never altogether idle, and during most of the summer of 1871 he was attached to the British Geological Survey and worked with the late J. Clifton Ward in the Cumberland Lake district. Returning to Canada in 1872, he was engaged for some months in examining and reporting upon mineral properties in Nova Scotia, and subsequently went to Quebec, where he delivered a course of lectures on chemistry at Morrin College, which was attended by a large and appreciative class.

In 1873 he was appointed Geologist and Botanist to Her Majesty's North American Boundary Commission, which had been constituted to fix the boundary line between British North America and the United States from the lake of the Woods to the Rocky mountains, and which had then been at work for over a year. There are but few corners of the earth which now appear so far off as did the great Northwest at that time—a veritable *terra incognita.* Fort Garry, now the city of Winnipeg, was the last outpost of civilization, and the party had to travel on horseback or on foot, the provisions and equipment being transported in Red River carts.

During the two years in which he was a member of the Boundary Commission, he accumulated materials for his elaborate and very valuable "Report of the geology and resources of the country in the vicinity of the 49th parallel," accompanied by maps and many illustrations, which was published in Montreal in 1875. This volume, which is now looked upon as "one of the classics of Canadian geology," is a model of what such reports should be—scientific facts being clearly and succinctly stated and the conclusions logically drawn. The main geological result arrived at was the examination and description of a section over 800 miles in length across the central region of the continent, which had been previously touched on at a few points only, and in the vicinity of which a space of over 300 miles in longitude had remained even geographically unknown. The report discussed not merely the physical and general geology of the region, and the more detailed characteristics of the various geological formations, but also the capabilities of the country with reference to settlement. The whole edition has been long since distributed, and the volume is now exceedingly scarce and difficult to obtain. While attached to the Boundary Commission, Dawson made large collections of natural history specimens, which were forwarded to England and found a home in the British Museum, as well as at Kew and elsewhere. The British Museum obtained no less than seventeen species of mammals not previously represented in its collections.

In connection with this work he also prepared a "Report on the Tertiary lignite formation in the vicinity of the forty-ninth parallel," as well as papers on the "Superficial geology of the central regions of North America," the "Marine Champlain deposits on lands north of lake Superior," "The fluctuations of the American lakes and the development of sun spots," the "Occurrence of foraminifera, coccoliths, &c., in the Cretaceous rocks of Manitoba," etcetera.

When the work of the Boundary Commission was brought to a close, he received in 1875 an appointment as Chief Geologist on the staff of the Geological Survey of Canada, and began the long series of explorations in the northwest and British Columbia which brought such credit to himself and his country. In 1883 he was made Assistant Director of the Survey, and in 1895, on the retirement of Doctor Selwyn, he succeeded him as Director. This position he held at the time of his decease.

His field work while connected with the Survey was carried on almost exclusively in British Columbia and the Northwest Territories, and the excellent character of this work contributed largely to the great development of the mining industries in these parts of the Dominion during recent years, for his reports though thoroughly scientific always took account of the practical and economic side of geology, and accordingly commanded the attention and confidence of mining capitalists, mine managers, and others interested in the development of the mineral resources of the country.

To outline the results of Dr Dawson's geological work in this western half of Canada would be to write a sketch of the geology of that part of the Dominion. Practically nothing was known of the geological relations of that vast district before he commenced his labors there. Now a large part of it has been mapped and studied geologically, while a general knowledge of the geological structure and the resources of the whole area has been obtained. This great work may be said to be due to Dawson, for it was carried out either by him personally or by his assistants and immediate successors in the field, men who were trained by him and derived their zeal for the work from his illustrious example.

Although a man by no means robust physically, much of this exploratory work was carried out in districts and under conditions which would have taxed the endurance of many a stronger man, as, for instance, his work in the Queen Charlotte islands in 1879, and, later, his exploration of the Yukon district and the adjacent portions of northern British Columbia. He felt an especial interest in the great regions of the north, about which until recently so little was known, and in 1887, having made a careful search through all the accounts left by the Arctic explorers, and having examined the geological collections brought back by certain of them, he published a "Geological map of the northern portion of the Dominion of Canada east of the Rocky mountains," with accompanying notes, in which all the existing information concerning the geology of this remote region was set forth. He subsequently published a paper "On some of the larger unexplored regions of Canada," which also attracted much attention and led to explorations being undertaken in several of the areas in question. The extent and character of his geological work may be gathered from the titles of his papers, which will be found in the accompanying bibliography by Doctor Ami.

Doctor Dawson was a prolific writer. In addition to his numerous and voluminous official reports, he contributed many papers on geological, geographical, and ethnological subjects to the scientific magazines and to the Transactions of various learned societies, both on this continent and in England. His last contribution was his address as President of this Society, the proofs of which he read only a day or two before his death.

With regard to his ethnological work we cannot do better than quote from Mr W J McGee's recent appreciative notice in the *American Anthropologist.* Mr McGee says:

> "While several of Doctor Dawson's titles and the prefatory remarks in some of his papers imply that his ethnological researches were subsidiary to his geologic work, and while his busy life never afforded opportunity for monographic treatment of Canada's aborigines, it is nevertheless true that he made original observations and records of standard value, that much of his work is still unique, and that his contributions, both personal and indirect, materially enlarged knowledge of our native tribes. It is well within bounds to say that, in addition to his other gifts to knowledge, George M. Dawson was one of Canada's foremost contributors to ethnology, and one of that handful of original observers whose work affords the foundation for scientific knowledge of the North American natives."

Dawson's most notable contribution to ethnology was undoubtedly his memoir on the Haida Indians of the Queen Charlotte islands; but he also published "Notes on the Indian tribes of the Yukon district and adjacent northern portion of British Columbia," a valuable memoir entitled "Notes and observations of the Kwakiool people of Vancouver island," "Notes on the Shuswap people of British Columbia," and many other papers.

Doctor Dawson also rendered important public service in connection with the Bering Sea arbitration. As one of the British commissioners, he spent the summer of 1892 in the Bering Sea region for the purpose of inquiring into the facts and conditions of seal life. The report of the commission constituted the case of Her Majesty's government, and I remember hearing at the time a high tribute paid to Doctor Dawson's ability by one of the gentlemen connected with the United States side of the case in the statement that had it not been for Doctor Dawson's evidence and arguments a finding much more favorable to the United States would probably have been rendered. In connection with his services on this arbitration he was made a companion of the Order of Saint Michael and Saint George (C. M. G.).

He received the degree of D. Sc. from Princeton in 1877 and the degree of LL. D. from Queen's University in 1890 and from McGill University in 1891. In the same year he was awarded the Bigsby gold medal by the Geological Society of London for his services to the science of geology, and was elected a Fellow of the Royal Society.

In 1893 he was elected President of the Royal Society of Canada. In 1896 he was President of the Geological Section of the British Association for the Advancement of Science, at its Toronto meeting, and in 1897 was awarded the gold medal of the Royal Geographical Society. In 1900 (last year) he was President of this Society. Doctor Dawson also occupied many other honorable positions and received many other distinctions which can not here be mentioned.

He usually enjoyed excellent health and had remarkable capacity for hard work, but he succumbed very suddenly, on the 2d of March last, to an attack of acute bronchitis, after an illness of but two days. He was a man of even more versatile gifts than his father, but, like him, possessed of an unusual combination of scientific insight, literary ability, and administrative capacity. He was a man of broad views, clear and judicial frame of mind, modest and retiring, but withal an excellent conversationalist. He won the esteem of all and his loss will be keenly felt by his very large circle of friends.

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In the absence of the author, the following memoir was read by the Secretary:

MEMOIR OF RALPH DUPUY LACOE

BY DAVID WHITE

Ralph Dupuy Lacoe died at his home in West Pittston, Pennsylvania, on February 5, 1901, in the seventy-seventh year of his age. He was respected by the entire community, esteemed by all who knew of his life work, and beloved by those who had the opportunity to know himself. His death was a loss to science.

Mr Lacoe's father, Anthony Desiré Lacoe, originally spelled "Lecoq," was born near Havre, France, and died in Luzerne county, Pennsylvania, in 1883, at an age only four days short of 103 years. His mother, Emelie

Magdaléne Lacoe, was the daughter of Huguenot parents who emigrated from Bordeaux and Nantes to Saint Domingo, whence her father, Jean François Dupuy, gentleman, escaped to the United States in 1791 with the loss of his estate, being exiled by the success of the negro insurrection.

Ralph, the youngest son of the Lacoe family, having no other educational advantages than the country schools, learned his father's trade, that of carpenter; but the slender advantages of his station were supplemented by his excellent mother, and in his early years of work he taught school for a short period, having among his pupils Bridget Clary, who afterward became his wife. He began the foundation of his modest wealth about 1850 by cutting railway ties on his grandfather's land and investing the proceeds more or less fortunately in coal lands not far from his home in the then largely undeveloped Lackawanna anthracite coalfield. Pending the improvement of the property he continued his work as carpenter. By honesty and intelligent industry he gradually became real estate dealer, manufacturer, banker, financier, and public officer, though never a politician as that term is commonly employed.

About 1865 Lacoe's health gave way from long-continued overwork, and he was obliged carefully to restrict the activity of his business career. However unhappy this may have been to himself and friends, and whatever loss it may have occasioned to the world of commerce, this enforced change in life was the beginning of his broadest and fullest living and increased usefulness to the world; for, although his health was never fully restored and his hearing became seriously impaired, the efforts for its recovery led insensibly to the development of new employments and purposes, including the desire to increase the sum of human knowledge.

It was while finding refuge in the mild winter climate of the Florida coast that Lacoe began first to amuse himself by collecting shells along the beach, and later by studying the marine life of the coast. On returning to Pennsylvania he took back with him a growing interest in natural history study, and before long he had entered upon the task of collecting the fossils from the Coal Measures of the Pittston region. This work he carried on with the greatest enthusiasm and enjoyment, finding in it a most recuperative and healthful relaxation from the cares and responsibilities of business. Lacoe often remarked that he owed added years to the out-of-door life and pleasure of collecting. At first his work was that of a collector and amateur; later it became systematic and definite in its scope.

It was not long before he came into communication with Lesley, the state geologist, and Leo Lesquereux, who was then preparing his great work on the Coal Flora of the United States for the Second Geological

Survey of Pennsylvania. The acquaintance ripened into a warm friendship between paleobotanist and patron that lasted until the death of Lesquereux in 1889. Meanwhile Lacoe's work in the Carboniferous flora had broadened out to include the plant life of the entire Paleozoic, and he had set about gathering the great collection to which we owe a large portion of our knowledge of the Paleozoic floras in America. Not only did he gather material from the Pittston-Wilkesbarre Coal Measures in the Northern anthracite field, but he extended his efforts to the other anthracite fields, to the Lower Carboniferous and Devonian of eastern Pennsylvania and the southern Virginian region, and to the Coal Measures of southern Tennessee, of Georgia, Arkansas, Missouri, Kansas, Illinois, and Rhode Island. In this work he hired collectors from time to time, besides purchasing many additional collections. He traveled in Great Britain and Europe, and by purchase or exchange procured Paleozoic plant collections from the British, French, and German coalfields, as well as from New Brunswick and Nova Scotia. Later he added collections from the Trias of New Jersey and Virginia, from the Dunkard formation of West Virginia, the Permian of Colorado, the Dakota of Kansas and Nebraska, the Upper Cretaceous of Colorado and Montana, and the Green River group of Wyoming. After a time he became interested in the remains of insect and myriapod life, which are seldom found except in association with plant remains, and concerning which very little was known; and this interest increased to the end of his life. In his later years he also added a large number of crustacean, fish, and molluscan fossils to his already enormous collection.

It would be wrong to conclude that Lacoe was a mere collector, even though systematic, or that his main object was the accumulation of a surpassing collection of fossils, duly accompanied by labels and ornamented by showy specimens. Realizing the very great handicap to the progress of paleontology due to the enormous labor and expense of discovering, exhuming, and intelligently preparing the fundamental materials from which the paleontologist must work out his results, he chose for his first service to science the task of securing this material and properly placing it in the hands of the paleontologists. His purpose was to systematically gather and put before the most eminent specialists the raw material which should contribute to our knowledge of the nature and characters of the plant and insect life of the ancient epochs; which should show the horizontal and vertical distribution of the types and their significance regarding genetic sequences and stratigraphical characteristics, and which should throw light on the questions of continental relations and climatic conditions. This raw material he submitted for elaboration to Lesquereux, Dawson, Scudder, Cope, Hall, and

Packard. But Lacoe's services to paleontology did not stop with procuring the collections from which the specialists should work out the results; for in some instances he made it possible for the specialist to more fully devote his time to paleontological study, while in other cases he defrayed the expenses for the costly drawings so necessary to adequate paleontologic publication.

A very imperfect conception of the extent to which the Lacoe collections had already contributed to our knowledge of fossil plants and insects may be gained from a review of the pages of "The coal flora" and the monograph of the flora of the Dakota group, or from Scudder's many papers on the Paleozoic and Tertiary insects of North America. The greater part of the correlative and stratigraphical data included in Lesquereux's great work, "The coal flora," are due to the efforts of Mr Lacoe and his interest in the investigations. The most important portion of the fossil plant material in the state collections appears to have been donated by him. He was also bearing the expense of the study and preparation of the manuscripts and illustrations for a supplementary volume of "The coal flora," to be published by the state, when the failing health and death of Professor Lesquereux left the work incomplete.

In 1891 the collections in Mr Lacoe's hands had increased until they more than filled the entire upper floor of the Pittston First National Bank building, the large hall of which constituted in effect a museum of no mean rank, though on account of the modest and retiring attitude of the founder its very existence was unknown to most residents of the city. It was in that year that he determined to place the great collection, containing many hundreds of types of fossil plants, insects, crustacea, and fish, in a suitable fireproof repository, where they should receive the necessary preservative care and where they should for all time be accessible to specialists. On account of the painful neglect of such collections that he had witnessed in most municipal and university museums, he determined to place the entire record portions of the collections, including the types, stratigraphical, geographical, and study series, in the keeping of the National Museum in Washington, which he believed was destined to be the center of biological and geological research in this country.

The removal of the fossil plant and fish collections, filling 315 boxes, was completed in 1895, by far the greater portion of the specimens being labeled and catalogued in Pittston. The fossil insect, myriapod, and crustacean collections were forwarded to Washington in 1899. The great collection intrusted by Lacoe to the care of the government embraced about 100,000 Paleozoic plant fossils, including over 575 described or figured specimens; 800 Dakota plants, including a large number of types; nearly 5,000 specimens of fossil insects, of which over 200 are types, and 400 specimens of fossil vertebrates. It also contained a large amount of unpublished plant material, besides several thousands of insects partially reported on by Doctor Scudder.

Besides his great gift to the National Museum, Mr Lacoe also donated a large collection of fossil plants, mostly labeled and arranged in cases, together with about 5,000 specimens representing 1,200 species of fossil mollusca, to the Wyoming Historical and Geological Society, of which for a number of years he was trustee and paleontological curator, and in whose welfare and active work he was deeply concerned.

Lacoe's scientific work did not cease with the donation of the collections. Even during and after the installation of the great type and study series in Washington he continued making important additions to both the fossil plant and insect sections, the accessions being obtained from regions or horizons of especial importance from the biological, geographical, or stratigraphical standpoint. At the time of his fatal illness negotiations were under way for the acquisition of plant material to assist in the correlation of the New Brunswick and Nova Scotia Carboniferous formations with those of the Appalachian region.

In the questions of the origin and early history of the principal insect families, as well as the true relationship of the insects found in the earlier formations, he entertained the keenest interest. Believing that the current speculative phylogenetic generalizations drawn from Mesozoic and Paleozoic insect remains were uncertain and unsatisfactory, as well as desultory, he was strongly of the opinion that the true relationship and paleontological history of the insect orders must first be worked out as thoroughly as possible from the fossils in the later formations. After that they should be traced backward step by step through the earlier formations of the Tertiary and Mesozoic, the remains of each earlier epoch being interpreted in the light of the knowledge first gained from the later period. The first step in his plan was to make ample collections from the insect localities hitherto discovered in the Tertiary. In this most important and philosophical line of research he had already gotten so far as to secure large collections, embracing several thousands of specimens from the classical type localities to the Upper Rhine region, and he was making arrangements for extensive collecting from the Tertiary insectiferous beds of the western states when his cherished hopes and plans were cut short by death.

As we have seen, Lacoe's chief services to science were those of a patron in the finest and best sense of that term. His aim was not to make gifts of large sums of money or of gross collections to some museum, university, or scientific society. Had he done thus he could hardly have accomplished so much or so well. He made it his business to systematically and wisely gather data for unraveling the early history of plant and insect life on the globe. He not only placed these data in the hands of the highest authorities, but when necessary he sustained the paleontologist in his investigation and aided in the publication of his work.

But he was more than a mere patron of science and more than an amateur. He himself was a man of science. Debarred for many years by partial deafness from easy conversation, he sensitively avoided publicity and social life and applied himself more closely to geological and other scientific reading and to the study of the collections about him. His well chosen library is supplied with a large number of scientific serials and the publications of numerous learned societies. Respecting the literature relating to fossil insects and paleozoic plants it is excelled by the libraries of probably not more than four institutions on this continent. Finding the greater portion of the literature on these subjects written in the French or German tongues, he mastered sufficient of both to enable him to carry on the study of the fossils before him. He was well and broadly informed in geology and general natural history. Concerning the stratigraphy of the Wyoming region and the northern anthracite coalfield he was an authority. In the recognition and differentiation of the genera and species of Paleozoic plants he became an expert, and in the latest years of his paleobotanical study he was fully competent, so far as knowledge or experience was concerned, to have determined, described, and published the greater part of the Paleozoic fossil plant material coming into his hands. Yet so modest and unassuming was he, so small an estimate had he of his own ability and attainments; so wholly wanting in the pride of species-making and authorship, and, withal, so anxious was he to obtain the best scientific results from the investigation of the various classes of fossils, that he was accustomed, to the last, to transfer to the most eminent specialists even the fossils in whose knowledge he himself was a specialist of high rank. In the three short papers which comprise his publications (see "Bibliography" following this memoir) he described neither genus nor species, and among the numerous representatives of the commonest and most easily recognized species there are in his collection comparatively few specimens whose labels show himself to have been the authority for their determination.

Unlike most self-made men, Lacoe was a man of culture and refinement. He was conscientious, studious, and methodical in his scientific as well as in his business affairs, while at the same time he was artistic in his tastes. In the quiet retirement of his home life he was gentle, kindly, and genial, though on account of sensitiveness due to his imperfect hearing he was slow to make new acquaintances. He was strong, earnest, noble-minded, and generously just, yet not lacking in humor or amiability of companionship. To know him was both to love and to admire him. His friendship was always helpful and inspiring. If he was deliberate in commendation, his compliments were always full of kind thoughtfulness and absolute sincerity. He was fond of encouraging and aiding young men, many of whom owe their success in life to the benefit of his friendship and the lesson of his exalted motives.

The fine quality of Lacoe's scientific spirit was well shown in the terms by which his great gift to science was intrusted to the keeping of the National Museum. In the simple words of the offer he stipulated only that the collection in its entirety should be known as the Lacoe collection; that additions might be made to it by exchange or further contributions by the donor, and that it should be kept "accessible to scientists and students without distinction, under such proper rules and restrictions as may be deemed necessary for the preservation from loss or injury of the specimens." As we have seen, his liberal designs for the further increase of the paleontological material were destined to be but partly carried out by himself.

The greatest and most enduring monument to Lacoe's devotion to and work for science is the Lacoe collection itself. Carefully guarded against danger or deterioration, it will be increased from time to time by exchanges or additional gifts. Its types, from the hands of Lesquereux, Dawson, Cope, and Scudder, will be consulted and reëxamined by the savants of paleontology for centuries to come. Students of life distribution, climate, and of evolution will review its suites of collateral specimens, and their records will supplement the records of the great paleontologists of the past who participated in its original elaboration. Thus Lacoe's work, which seemed so unhappily cut off in the midst of his broadest plans for the increase of human knowledge, will continue to go forward.

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*MEMOIR OF JOSEPH LE CONTE**

BY W J MCGEE

In the absence of the author, the following memoir was read by Richard E. Dodge:

MEMOIR OF THEODORE GREELY WHITE

BY J. F. KEMP]

Theodore Greely White was born in New York August 6, 1872, and passed away, after a brief illness, in the city of his birth, July 7, 1901. He fitted for college at the Columbia Grammar School and entered the School of Mines of Columbia University in the course in geology and paleontology in October, 1890. He received the degree of Ph. B. June, 1894, and immediately registered for graduate work as a candidate for M. A. and Ph. D. The former degree he received in 1895 and the latter in 1898. In 1896 he was appointed assistant in the Department of Physics, Columbia University, and held that position until 1900, being especially in charge of the experimental work in optics. The organization of this particular laboratory at the new site in Columbia University largely fell to him, and in the work he displayed administrative ability which won for him the warm commendation of his superiors. As a boy, Doctor White early manifested a special interest in natural science. His Ph. B. thesis was a description of the geology of Essex and Willsboro, towns on lake Champlain. In connection with this work he became interested in the faunas of the Trenton strata in the Champlain valley and determined upon a study of them as his thesis for Ph. D. To this end he studied them not alone in the Champlain region, but all around the Adirondack crystalline area. His thesis for the M. A. degree was a petrographical description of the Quincy granite near Boston, which he undertook in association with Professor Crosby, of the Massachusetts Institute of Technology.

The full results of Doctor White's work upon the Trenton fossils have not yet been published, as the manuscript remains to be issued. His chief results were, however, presented to this Society in 1898. Doctor White was a man of indefatigable industry and of great perseverance. Besides his efforts in geology, he had a number of additional undertakings in hand. He was especially interested in the parish work of the Church of the Holy Communion, Sixth avenue and Twentieth street,

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The memoir was not read at the meeting, but is here noted in its place, as on the printed program. It has not been possible for Mr McGee, who consented to prepare this memoir, to furnish the manuscript in time for publication in this volume. It will probably appear in volume 14.

New York, and the past spring he made up his mind to devote himself to a life work among its young men. He was largely instrumental in founding Gordon House, a club house and center of interest for them, and to it he has bequeathed his estate. Indeed, during an excursion to the neighboring seashore with his young men friends of the club, he became exhausted while bathing in the salt water and took a cold which developed into pneumonia and caused his death after a brief illness. He has left a large circle of sincere and devoted friends who can with difficulty reconcile themselves to his loss.

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Following the presentation of memorials the President, Dr Charles D. Walcott, assumed the chair.

The Society was welcomed to Rochester and to the University of Rochester by the president of the University, Rush Rhees, LL. D., and President Walcott responded.

Announcement was made that the Ward's Natural Science Establishment, located across the street from the meeting place, would provide a mid-day lunch each day of the meeting for all Fellows who wished to visit the institution.

The presentation of scientific communications was declared in order and the first paper read was

ORDOVICIAN SUCCESSION IN EASTERN ONTARIO

BY H. M. AMI

[*Abstract*]

The paper indicated the succession of paleozoic sediments in that portion of the province of Ontario, Canada, which is traversed by the Frontenac axis or ridge of

Archean rocks which crosses the Saint Lawrence river between the city of Kingston and Brockville and connects with the great Adirondack massif to the south.

The Frontenac axis divides the Ordovician strata, to the east as well as to the west, into two series, which, though not very distant, geographically speaking, are nevertheless marked by important features and differences.

On the east and west sides of the axis the following order of succession in the geological formations obtains:

ORDOVICIAN EAST OF THE FRONTENAC AXIS

Formations	*Character of Strata*
VII. Lorraine	Buff weathering and dark silicious shales and mudstones.
VI. Utica	Dark brown and black bituminous shales and limestones at the base.
V. Trenton	Dark gray, impure, and semicrystalline fossiliferous limestone.
IV. Black River	Heavy bedded and hard compact fine-grained impure limestones, etcetera.
III. Chazy	Limestones, shales, sandstones, and grits. Shallow water deposit at the base.
II. Beekmantown (Calciferous)	Dark gray, impure magnesian limestone or dolomites, cavernous and fossiliferous.
I. Potsdam	Light yellow and rusty colored sandstones and conglomerates, shore deposits resting on the Archean crystal lines.

ORDOVICIAN WEST OF THE FRONTENAC AXIS

V. Lorraine	Arenaceous shales and mudstones, at times very fine grained argillites.
IV. Utica	Dark brown and black fossiliferous shales, &c.
III. Trenton	Gray impure fossiliferous limestones.
II. Birdseye and Black River	Heavy bedded impure fossiliferous limestones and fine-grained compact lithographic beds at the base.
I. Rideau	Mostly red and yellow (at times green) colored sandstones; shallow water deposit, false bedding prevalent, a basal series resting unconformably upon the subjacent Archean crystallines.

An attempt is made to solve the problem arising from the discussion of these differences in the sedimentaries on each side of the axis, and in the remains of life entombed in them.

Remarks were made on the subject of the paper by Bailey Willis, W. M. Davis, and the President. An abstract is printed in *Science*, volume xv, January 17, 1902, page 82.

The following paper was read by Mr Shimer:

HAMILTON GROUP OF THEDFORD, ONTARIO

BY H. W. SHIMER AND A. W. GRABAU

The paper was discussed by J. M. Clarke, H. S. Williams, and H. M. Ami. It is printed as pages 149–186 of this volume.

The last paper of the morning session was the following:

TRAVERSE GROUP OF MICHIGAN

BY A. W. GRABAU

[*Abstract*]

Two sections, one on Thunder bay and the other on Little Traverse bay, show the strongly calcareous facies of the strata, which is most marked in the western section. In both sections the upper limit of the Traverse group is indicated by the Saint Clair black shale, and the lowest portion of the group is a bed of blue clay 80 feet thick. The fauna varies with the rock. The reef character of the limestone strata was discussed.

Questions and remarks were made on Mr Grabau's paper by H. S. Williams and the President.

At 12.20 p m the Society adjourned for the noon recess. At 2 p m the Society met and resumed the reading of papers. The first paper was

*LOWER CARBONIFEROUS AREA IN INDIANA**

BY T. C. HOPKINS

[*Abstract*]

In the southern and west central portions of Indiana the strata of Lower Carboniferous age are divided into five well marked lithologic units as follows:

The Huron limestone and sandstone.
The Mitchell limestone.
The Bedford oolitic limestone.
The Harrodsburg limestones and shales.
The Knobstone shales and sandstones.

The upper division, the Huron, is overlain by the Mansfield sandstone, a heavy bed of sandstone and conglomerate which forms the base of the Coal Measures, while the lower division, the Knobstone, is underlain by the Devonian black shales.

The lower group consists of a thick series of drab-colored shales, which locally grade into sandstones of sufficient firmness to be quarried in some places for building stone. It is one of the thickest formations in the state, reaching in places more than 500 feet. It forms many quite prominent hills or knobs in the central and southern portions of the area, which suggests the origin of the name.†

The second division, the Harrodsburg limestone, is so called from the village of that name in Lawrence county, where the rock is well exposed. It consists of crystalline to subcrystalline fossiliferous limestones, in places very crinoidal, with more or less intercalary shale. It forms a transition bed from the underlying

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*By permission of the State Geologist of Indiana. Full paper published in the 26th Ann. Rept. State Geologist of Indiana along with a new geological map of the State.

† For detailed description of this group see paper by J. F. Newsom in 26th Ann. Rept. State Geologist of Indiana, 1901.

Knobstone to the overlying oolitic limestone. It is characterized by the abundant crinoidal remains, the crystalline texture, and the geodes occurring in it. The geodes are especially abundant in the central part of the area. There is generally no sharp line between the Harrodsburg and the underlying Knobstone, but the line separating it from the overlying oolitic limestone is well marked.

The third division includes the famous Bedford oolitic limestone, one of the most widely known building stones in the United States. It reaches its greatest commercial importance in the central portion of the area in Lawrence and Monroe counties around Bedford and Bloomington as centers, where it forms a bed twenty to one hundred feet thick and is of quite uniform texture and structure. In the northern extension it loses the massive structure, the bedding planes become more numerous, and in many places the stone is more coarsely crystalline. It is quite fossiliferous in many places. It is named from Bedford, the county seat of Lawrence county, and belongs to the Saint Louis stage of the Mississippi Valley deposits.

The Mitchell limestone, named from Mitchell, in Lawrence county, consists of a compact blue to drab-colored limestone containing locally much chert. The chert occurs in nodular masses and irregular layers, in some places replacing a large part of the limestone. Some of the layers have such a smooth, even texture as to resemble lithographic stone. It is characterized topographically by the numerous sink-holes and caves. It contains a great many large caves, and the surface, dotted with sink-holes, shows its widespread cavernous character, which is further indicated by the numerous "lost rivers," sinking streams, and large springs. It is used in large quantities for burning lime and in limited quantities as building stone, flagstone, and road metal.

The Huron group, known in some of the older reports as the Chester, is in some measure a transition bed between the underlying limestone and the overlying sandstone. It consists of alternating beds of sandstone and limestone. In Orange county there are generally three limestones and two sandstones, but farther north the number and character of the layers are subject to local changes, and in places shales replace the sandstone wholly or in part. There are small local deposits of coal in the shale. The limestones are more coarsely crystalline than the underlying Mitchell. One of the beds frequently has a reddish tinge, and in many places the limestone is in part oolitic, but differs from the Bedford oolitic limestone in being a true concretionary oolite.

The calcareous beds thin out to the northward along the outcrop, but not uniformly. The Mitchell is more persistent than either the underlying Bedford or the overlying Huron. The Bedford loses its massive character and its chief value as a building stone in southern Owen county, but extends through Owen and Putnam into southern Montgomery county. The Huron thins out rapidly in Owen county and does not appear north of the Big Four railroad in Putnam county, except possibly in one locality. The most northern outcrop of the limestones is in southern Montgomery county near Waveland. North of this point the massive carboniferous (Mansfield) sandstone rests conformably on the Knobstones, with all the limestones lacking, except a very crinoidal one, which occurs at a number of localities in Montgomery county, and which is probably the chronological equivalent of the Harrodsburg limestone. There is quite a pronounced unconformity between the base of the Coal Measures and the Lower Carboniferous, especially in the northern area, as shown (1) by the outlyers of the Coal Measures sandstones lying in erosion channels many miles east of the eastern outcrop of the parent rock; (2) the typical basal conglomerate lying at the contact, and (3) the absence of the limestones.

Questions or remarks were made by several Fellows.

The second paper was

GEOLOGICAL HORIZON OF THE KANAWHA BLACK FLINT

BY I. C. WHITE

Remarks on the paper were made by J. J. Stevenson, Bailey Willis, and the author. The paper is printed as pages 119–126 of this volume.

A telegram of greeting was received from A. C. Lawson, as Secretary of the Cordilleran Section, and the Society by vote instructed the Secretary to send an appropriate reply.

The third paper was

CORRELATION OF THE COAL MEASURES OF MARYLAND

BY W. B. CLARK AND G. C. MARTIN

The paper was discussed by I. C. White, J. J. Stevenson, and Bailey Willis. It is printed as pages 215–232 of this volume.

The next paper was

GEOLOGY OF THE POTOMAC GROUP IN THE MIDDLE ATLANTIC SLOPE

BY W. B. CLARK AND A. BIBBINS

Remarks or questions were made by T. C. Hopkins, W. N. Rice, and J. A. Holmes. The paper is printed as pages 187–214 of this volume. An abstract is printed in *Science*, volume xv, page 84, January 17, 1902, under a different title.

The following paper was then read:

JOINT VEINS

BY G. K. GILBERT

[*Abstract*]

Certain thin beds of limestone inclosed in Cambrian shales of Rainbow valley, House range, Utah, are traversed by systems of parallel veins. These veins represent joints and afford a convenient opportunity for the study of joint arrangement. The intervals between parallel joints are so small that many characters, including the interrelations of systems, are well exhibited in hand specimens. It is suggested that the scale of joint systems is in part determined by the thickness of the formation traversed. At least twelve systems occur in one specimen. Some of

these intersect at narrow angles. They are in two groups, apparently related to strike and dip. Some veins are interrupted without continuation, others with continuation *en echelon.*

The paper was discussed by J. E. Wolff, B. K. Emerson, Bailey Willis N. H. Winchell, A. C. Lane, and the author.

The last paper of the session was the following:

REGENERATION OF CLASTIC FELDSPAR

BY N. H. WINCHELL

Already several American geologists have noted enlargements of feldspar crystals and fragments of crystals in clastic strata, and some have described most of the phenomena to which I desire to call attention. Perhaps the earliest of these was Irving, who, in association with Van Hise, in 1884 described quartz and feldspar enlargements in various sandstones in the Lake Superior region.[*] Professor Van Hise gave what appears to be the first description of feldspar enlargements in American rocks. He illustrated the extension of albite twinning bands in a plagioclase fragment into the new rim formed in a Keweenawan sandstone underlying a sheet of diabase.

The next description of similar phenomena in American literature seems to have been that of Dr E. Haworth,[†] but in this case the original feldspar nuclei were not recognized as clastic, but the enlargements were supposed to have been formed on the outer surfaces of crystals after solidification from a liquid magma before final cooling. Doctor Haworth remarks that "of course this kind of enlargement is entirely different from those in fragmental rocks described by Irving and Van Hise for quartz, and by Van Hise for orthoclase and hornblende." He does not, however, point out any difference, except that in the Missouri granite the rock is massive and was once nearly or quite molten, whereas in the case of the Keweenawan sandstone the rock is plainly clastic. This constitutes, it must be admitted, a difference in the rocks in which the phenomena are seen. The actual phenomena of the enlargements, however, are quite identical with phenomena described since in admittedly clastic rocks.

In 1891 Dr J. E. Wolff gave a lucid exposition of the metamorphism of clastic feldspar in a clastic rock in western New England, calling attention to some of the same phenomena as mentioned by Haworth.[‡] He found that new albite and new microcline are formed about original clastic fragments, and that the enlargements are fresh and glossy while the nuclei are clouded by great numbers of minute inclusions. He suggests that the so-called porphyritic albite crystals found in the schist overlying this conglomerate may be due to an original replacement of some other feldspar fragment by albite material, and that the growth of the albite crystal after total replacement of the fragment was continued beyond the limits of the original grain, leaving some of the iron products of such transformation in the form of scattered or banded grains of oxide of iron in the regenerated crystal. The bright rims of fresh feldspar surrounding the old feldspar grains he does not unhesitatingly ascribe to new growths on the original grains, but suggests that they are in part due to an actual replacement of the outer part of the detrital grain by the new feldspar. This suggestion is borne out by the fact, observed in the same conglomerate and in other rocks, that the fresh feldspar penetrates along fissures well within the original old feldspar, forming tongues and irregular areas connected with the rim in all optic characters, and demonstrating that the new feldspar, which is characteristically abundant in the rims, pervades more or less the entire clastic grain. Mr Wolff also called attention to the fact that probably both albite and microcline had formed independently of any preëxisting nuclei.

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[*] Secondary enlargements of mineral fragments in certain rocks. Bull. U. S. Geol. Survey, no.8, 1884.

[‡] A contribution to the Archean geology of Missouri. American Geologist, May and June, 1888.

[‡] Metamorphism of clastic feldspar in conglomerate schist. Bull. Mus. Comp. Zool., vol. 16, 173.

The same conglomerate schist was the subject of a more general treatment by Dr C. E. Whittle in 1892.* Connected with the description of the occurrence of various secondary minerals, such as ottrelite, sericite, anatase, etcetera, he describes fully the alteration which the clastic feldspars have undergone. Mr Whittle calls attention to an important feature, due to what he calls the "clearing action of sericite," this mineral lying in belts parallel with the exterior clear rim, and along other clear belts that penetrate within the grain. He hence is disposed to attribute the clear rims not so much to enlargement of the original grains as to some subsequent action that eliminated the impurities. He also shows that in such metamorphism microcline is sometimes altered into plagioclase.

In the same year Dr W. H. Hobbs, in discussing the metamorphic schists of western Massachusetts, †dwelt at length on the so-called porphyritic feldspars of the albite schists of that region. He gives numerous cases of plagioclase feldspar, more or less oval in shape, exhibiting various kinds of alteration and regeneration. He figures an old feldspar that shows a granophyre structure. That this structure is not preserved from some former igneous condition of the feldspar is evidenced by the identity of extinction which it bears with the quartz surrounding the grain. He inclines to interpret the granophyre structure here as a secondary feature due to decay of the original feldspar. In other cases feldspar of different composition had partially replaced the original, and this new feldspar not only formed the rim, but constituted mottlings throughout the original grain. Doctor Hobbs mentions the same phenomenon as Doctor Haworth, namely, that frequently the cores of enlarged feldspars show crystal boundaries, while the enlargements are irregular. He considers this an indication that they are not of detrital origin, though the rocks are undoubtedly clastic. These changes, and others exhibited by the formation of staurolite, tourmaline, ottrelite, etcetera, Doctor Hobbs does not attribute to dynamic metamorphism, there being little or no evidence of crushing and shearing, but to "static metamorphism"—that is, a metamorphism due to pressure combined with heat and moisture acting over an extended area.

Besides the publication of these studies on enlargements of clastic feldspars, there are no others in America, so far as I know, prior to my own, recently published in the final report of the Minnesota Survey, volume v. It is the purpose of this paper to call attention to certain conditions in the alteration of clastic feldspar which should be carefully noted. As these conditions seem to depend on the degree of metamorphosing force to which the fragments may be subjected, they may be called phases or stages in a progressive change, or series of changes, through which feldspar crystals pass in normal petrologic history.

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*Some dynamic and metasomatic phenomena in a metamorphic conglomerate in the Green mountains. Bull. Geol. Soc. Am., vol. 4, 1892, p. 147.

†Phases in the metamorphism of the schists of southern Berkshire. Bull. Geol. Soc. Am., vol. 4, [1892], 1893, p. 167.

These phases are three:

The *first* is that of *decay*. A feldspar grain that is simply decayed can be identified under the microscope by a peculiar flecked appearance which usually begins by obscuring the margin, but finally permeates the whole grain. According to Professor Pumpelly, such decayed feldspars sometimes exhibit zones of greater or less alteration surrounding a core of undecayed feldspar.* The minute scales of sericite are then uniformly distributed throughout the body of the crystal, or at an earlier stage a kaolinization is apparent, creeping along progressively in the cleavages. This decayed condition is not a metamorphic state. It is not due to a forced recrystallization, but to slow weathering. It is truly an alteration of the feldspar, but it is not a regeneration. The feldspars in many of the Archean quartz porphyries exhibit this kind of alteration.

This decay sometimes takes on a different form. The feldspar seems to change wholly into an ultra-microscopic mosaic of quartz and feldspar, the little individuals of which are roundish but compactly adjusted together. The nature of this secondary feldspar it is difficult to determine. Feldspar fragments in the Ogishke conglomerate have been seen thus altered. It is possible that some faint dynamic or other force, or the chemical environments, were instrumental in determining this kind of alteration rather than the sericitic. So far as noticed, this alteration affects the feldspars of the basic sediments.

The *second*, or rimmed phase of regeneration, is that which has been frequently noted. In orthoclase, microcline, and plagioclase the process of decay is interrupted by a reaction resulting from dynamic or "static" metamorphism, and a regenerative process begins. This seems to revive the crystallizing force which is located and active in the very surface of a crystal; and while it expels some of the sericitic or epidotic particles it builds further feldspathic substances on to the original grain. The new growth is fresh and glassy, making a more or less continuous casing on the old core. At the same time the new growth enters the old grain, forming tongues or isolated small areas that polarize like the new matter of the rim, giving the semi-regenerated grain a broken and mottled aspect. This restoration of the old grain drives the sericite scales, the epidote, or the zoisite, and all other products of the earlier decay, toward the center of the original feldspar, or into groups that are prevailingly in the central part of the grain. It is probable, also, that the date of definite crystallization of these impurities into recognized minerals is cotemporary with this migration toward the center, and it is further probable, if the feldspar mass that immediately embraces them after their migration could be specifically determined, it would be found to be of the same species as that of the rim, at least in many cases. When the migration of the impurities toward the center is not perfect and the entire grain is not wholly renewed, it has been noted in numerous instances that the new feldspathic growths are not of the same species as the old grain. The crystal orientation is usually the same in the new as in the old, but not always. The albite mark may be continuous from the old into the new, or it may be interrupted. The carlsbad twin may be ignored by the new growths. If both new and old are orthoclastic, one may be deformed and the other not deformed orthoclase. The new feldspar may be twinned like microcline when the old is not. The new feldspar may be polysynthetically twinned when the old is not. Hence it appears that the new growths may vary in a great variety of ways in crystalline structure, both in specific designation and chemical composition, from the original grain. Such semi-renewed clastic feldspars are common in the Archean sediments of Minnesota. They have been described in the schists and conglomerates of the Taconic region of New England. There is no doubt that they can be found in many other places where clastic materials have been metamorphosed.

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* Relation of secular rock disintegration to certain transitional crystalline schists. Bull. Geol. Soc. Amer., vol. 2, 1901, p. 210.

In the *third phase* of feldspar enlargement the secondary growths are much extended. The original forms of the feldspar grains are nearly or wholly lost. The boundaries are jagged and even grown into the spaces between adjoining grains. Sometimes the new growths have surrounded adjacent grains of other minerals. This change in the feldspars is coördinated with similar transmutations in all the associated minerals. The result is the formation of a granitic texture by the recrystallization of the entire mass. In this case there can be no doubt of the unity of the feldspar species, whether in the new growths or in the remaining cores. The old cores have been thoroughly saturated with the new feldspathizing solutions. The sericitic or zoisitic particles remain, grouped at the centers of the feldspars; the clear and fresh growths spread outward in all directions, giving place, however, at their margins to other minerals, but extracting from the rock everywhere every atom of the chemical elements that can be seized on to promote their own development. The rock thus passes to a normal granite or diorite or other massif, according to the mineral composition.

This regrowth of feldspar is apparent, so far as examined by the writer, in nearly all the metamorphic and massive acid rocks. It has not always been interpreted in this way. Owing to the imperialistic sway of an old dogma as to a pronounced difference in origin between clastic and acid massive rocks, these regrowths have not been allowed to have their legitimate effect in petrological studies. When they have been seen in plainly clastic rocks they have been referred to simply as accidental, marginal enlargements, and when in crystalline or igneous rocks they have been explained as secondary growths in the original magma prior to consolidation, or after effusion as zonal increments after partial resorption, or as renewals of feldspar after partial fusion by a basaltic contact. There seems to be, however, no essential difference in the quality of this change from first to last. The difference is one of degree.

The inference that is to be drawn from a consideration of these successive phases in the metamorphism of feldspar relates to the genesis of granite and its allies. If it be true, in one instance only, that a granite can be shown to originate in this way, it is indicative of a law for the generation of all granites. If it be found that in many cases the same facts are grouped so as to point to the same law, it is sufficiently demonstrative of the universality of that law to warrant its adoption and incorporation into the petrology of the crystalline rocks.

Session of Tuesday Evening, December 31

The Society convened at 8.30 o'clock in the College chapel, Anderson Hall, for the presidential address. The title of the address was

OUTLOOK OF THE GEOLOGIST IN AMERICA

BY THE PRESIDENT, CHARLES D. WALCOTT

The address is printed as pages 99–118 of this volume.

Session of Wednesday, January 1, 1902

The Society convened at 9.50 o'clock a m, the President in the chair.

The report of the Council was taken from the table and adopted without discussion.

The Committee on Photographs submitted its report as follows:

TWELFTH ANNUAL REPORT OF COMMITTEE ON PHOTOGRAPHS

There have been no additions to the collection of photographs during the past year. Early last spring the committee appointed by the Council, consisting of Mr G. K. Gilbert, Mr J. S. Diller, and myself, made an examination of the entire collection and culled out such views as appeared clearly not to be of value. These comprised about one-third of the collection. The remainder, 1,431 prints, have been arranged by states and countries in alphabetic sequence and renumbered. A new catalog has been prepared, which gives titles of the photographs, their size, and the name of their taker, and, as far as possible, the negative number by which prints may be ordered. This catalog is now waiting for negative numbers of several groups of U. S. Geological Survey photographs formerly without numbers. These numbers are now being arranged by the chief photographer of the Survey, and they will soon be supplied. A classified subject-index of all the photographs has been prepared for publication with the catalogue. It will afford a ready means for the selection of views illustrating many geologic subjects. It is believed that the publication* of this new catalog and index will add greatly to the usefulness of the collection.

Respectfully submitted.

N. H. Darton,
Committee.

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*The catalog and index of photographs is printed as a regular brochure and forms pages 377–474 of this volume.

The report of the Photograph Committee was adopted and the usual appropriation of $15 was voted.

The Auditing Committee reported that the accounts of the Treasurer had been found correct, and the Society adopted the report.

The Council submitted its report on the matter of the proper pronunciation of the name "Cordilleran," which had been referred to the Council at the Washington meeting, 1899. It was recommended that the name be pronounced "Cor-dil-yé-ran." The report was adopted.

The first paper of the scientific program was

GEOLOGY OF SNAKE RIVER PLAINS, IDAHO

BY ISRAEL C. RUSSELL

[*Abstract*]

Suggestions in reference to the origin of the Snake River basin. Tertiary lakes. Extent and thickness of the Snake River lava and its relation to the Columbia River lava. Lack of evidence of fissure eruptions. Presence of numerous extinct volcanoes, both on the plains and among the neighboring mountains, which discharged great quantities of highly liquid lava. Distinction between cinder cones and "lava cones." The extensive lava flows from the Cinder buttes, which illustrate the mode of origin of the older members of the series of lava sheets to which they belong. Corrugated surfaces of recent lava streams passing into hollow pressure ridges. Origin of the characteristic ridges on the surfaces of the older lava sheets. Characteristics of lava flows which entered water bodies. Lava caves formed by the arching of a viscous crust on a lava stream, due to lateral pressure; to outflow of liquid lava from beneath a rigid crust; and to the blowing out of plastic lava by steam during the formation of parasitic cones. Evidence that "aa" surfaces are due to the breaking of a brittle crust on a lava stream on account of an underflow of still plastic lava. The canyon of Snake river; influence of lava sheets on its topography. Great springs on the northern side of Snake River canyon below Shoshone falls. The classification of springs. The term "canyon spring" defined. Remarkable spring-formed alcoves or small side canyons in the northern wall of Snake River canyon.

The paper was discussed by B. K. Emerson and J. E. Wolff. An abstract is printed in *Science*, volume xv, January 17, 1902, pages 85–86, the report of which the paper presented is a partial abstract, forms Bulletin no. 199 of the U. S. Geological Survey.

The two following papers were presented together and discussed as one, the second paper being a series of lantern illustrations:

STRATIGRAPHY AND STRUCTURE LEWIS AND LIVINGSTONE RANGES, MONTANA

BY BAILEY WILLIS

This paper is printed as pages 305–352 of this volume.

PHYSIOGRAPHY OF THE NORTHERN ROCKY MOUNTAINS

BY BAILEY WILLIS

The two papers were discussed by A. P. Coleman, C. D. Walcott, and the author.

The fourth and last paper of the morning session was

WALLS OF THE COLORADO CANYON

BY W. M. DAVIS

[*Abstract*]

The general profile of the canyon walls depends on rock structure, and not on a pause in the elevation of the plateaus. The variation of profile from the narrow canyon in the Uinkaret plateau to the wide canyon in the eastern Kaibab is due to variation in the character of the strata. The pattern of spurs and recesses varies with stage of dissection. The pattern commonly seen in the Red-wall cliffs is repeated in the Tonto cliffs where the latter are much worn. The pattern usually seen in the Tonto is repeated in the Red-wall where it is less worn. Brief mention is made of details connected with the unconformities seen in the canyon walls.

Remarks were made by the President.

The Society adjourned for the noon recess and reconvened at 2.30 p m, when the following paper was read:

ROCK BASINS OF HELEN MINE, MICHIPICOTON, CANADA

BY A. P. COLEMAN

The paper is printed as pages 293–304 of this volume.

The second paper was

EFFECT OF SHORELINE ON WAVES

BY W. M. DAVIS

[*Abstract*]

The paper described the transformations of waves as they run in on shorelines of different forms, with special reference to the refraction of waves on headlands and in bays, and to the formation of surf.

The third paper was

VARIATION OF GEOTHERMAL GRADIENT IN MICHIGAN

BY ALFRED C. LANE

[*Abstract*]

The rate of increase of temperature observed in deep mines and borings has attracted attention from time to time,* mainly in connection with the exceptionally low gradient of the copper country. Temperature observations from various parts of Michigan were given, which will be given more fully in the Annual Report of the State Geologist of Michigan for 1901.

Characteristic figures are the following:

In the copper country, where the mean annual air temperature is 49 degrees Fahrenheit or below (38.6 degrees), the temperature increases from 43 + degrees at 112 feet to 87 degrees at 4,900 + feet.

The gradient is somewhere about 1 degree Fahrenheit in 107 to 115 feet. In the deepest mine at Ishpeming the highest temperature obtained in July, in the nineteenth level, 900 feet below the surface, was 51 degrees. The mean air and 100-foot temperature are not far from the same, as in the copper country.

At Cheboygan we have: Mean air temperature, 41.6 degrees; at 408 feet (mainly through drift, flow of water), 51.8 degrees; at 1,360 feet, 61.6 degrees; at 2,700 feet, 73 degrees.

At Bay City we have from a mean air temperature of 45.4 degrees Fahrenheit and temperature of first flows at 102 feet of 47 degrees a rise to 97 degrees Fahrenheit at 3,455 feet.

At Grayling, from a mean air temperature of 43.4 degrees, we have a rise to 95.9 degrees at 2,600 feet, the most of this in the upper part, which was drift.

At Muskegon the mean air temperature is 46.8 degrees. The temperature of numerous flowing wells from the top of the bed rock at 240 feet is 53 to 53.5 degrees. In a well (Ryerson's salt well, abandoned, plugged at 1,200 feet) we have 53.2 degrees at 240 feet, 58.7 degrees at 650 feet, and 67.2 degrees at 1,150 feet.

The facts seem to point to a difference of air and soil temperature, due to the blanketing effect of snow, of half a degree to 4 degrees, according to location, and a gradient in surface deposits of 1 degree in 49 feet, more or less, in shale of 1 degree in 60, and in sandstone of 1 degree in 60 to 70 feet, while in limestone, trap and the denser rocks it is 1 degree to 100 feet and more, the denser and less porous rocks having greater diffusivities and lower gradients.

Tabulation of standard results on rock diffusivity seems to show that the density is the most important factor in diffusivity. Contradictory observations on rock-salt may be due to a diathermic effect which had not been eliminated.

The following two papers were read and discussed together:

ORIGIN AND DISTRIBUTION OF THE LOESS IN NORTHERN CHINA AND CENTRAL ASIA

BY G. FREDERICK WRIGHT

This paper is printed as pages 127–138 of this volume.

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* J. D. Everett, Report of Committee of British Association.
H. A. Wheeler, Am. Jour. Sci., vol. 32, 1886, pp. 125-137.
A. C. Lane, Mineral Industry, vol. 4, 1895, p. 767.
A. Agassiz, Am. Jour. Sci., vol. 50, 1895, p. 503.
A. C. Lane, Am. Jour. Sci., vol. 9, 1900, p. 435, and Annual Report for 1901 to the Board of Geological Survey of Michigan, p. 244.

AGE OF LAKE BAIKAL

BY G. FREDERICK WRIGHT

[*Abstract.*]

The region below lake Baikal is covered with strata of Tertiary (and possibly Triassic) age, containing coal. These beds are derived from the sediments which were carried by now existing streams into the basin from the surrounding mountains before the present lake came into existence. At the estimated rate of erosion, the entire lake would be filled in 400,000 years, whereas it is not a quarter full, and probably not one-tenth full. The age of lake Baikal is perhaps 100,000 years or less. That this region was formerly connected with the sea is shown by the species of seal found in lake Baikal, which are also found in the Caspian sea. Other evidence of recent submergence followed by reëlevation exists. A period of increased precipitation caused the freshening of all the waters of the inland lakes of this region.

Remarks were made on the papers by W. B. Scott.

Announcements were made by the Secretary regarding the dinner to occur in the evening, the reception tendered to the Society by the president of the University on Thursday evening, the local geological excursions suggested, if time allowed, and the new titles of papers added to the program.

The following paper was read by the senior author:

SOME ANTICLINAL FOLDS

BY T. C. HOPKINS AND MARTIN SMALLWOOD

[*Abstract.*]

A number of unique folds occur in several small and rather deep ravines in the vicinity of Meadville, Pennsylvania. They are of limited extent, both vertical and linear, and so far as known occur only in the bottom of the ravines. The relation of the folds to certain land-slip terraces suggests a cause for these folds.

Remarks were made by I. C. White, A. P. Brigham, I. C. Russell, J. J. Stevenson, and Mr C. J. Sarle, a visitor.

The following two papers were read and discussed as one:

DISTRIBUTION OF THE INTERNAL HEAT OF THE EARTH

BY T. C. CHAMBERLIN

[*Abstract*]

Assuming that Barus's law relative to the melting point of diabase under varying pressure is valid when extended to all the pressures and temperatures of the earth's interior, and assuming also that diabase is in this respect representative of

the material of the earth's interior, the paper discussed the primitive distribution of the earth's interior heat under both the gaseous and the planetary modes of aggregation, and drew certain tentative deductions relative to the possible consequences of the secular redistribution of this heat.

HAS THE RATE OF ROTATION OF THE EARTH CHANGED APPRECIABLY DURING GEOLOGICAL HISTORY?

BY T. C. CHAMBERLIN

[*Abstract*]

Since the classic computations of George Darwin relative to the tidal relations of the earth and moon, the doctrine of a high rate of terrestrial rotation in early geologic times has been widely accepted and has been made the basis of deductions relative to other important questions. The paper attempted to test the validity and quantitative applicability of this tenet by means of geologic phenomena, especially those of crustal deformation and the relations of sea to land.

The Society adjourned. No evening session was held, but the Fellows, with invited guests, had the annual dinner at the Whitcomb house.

Session of Thursday, January 2

The Society convened at 10 o'clock, Vice-President Winchell in the chair. No business was offered and the reading of papers was resumed. The first two papers were read and discussed as one.

USE OF THE TERMS LINDEN AND CLIFTON LIMESTONES IN TENNESSEE GEOLOGY

BY AUGUST F. FOERSTE

[*Abstract*]

The Lower Helderberg was named in Tennessee from its exposure at Linden, where it is but 12 feet thick, while the maximum thickness is between 75 and 100 feet. The advisability of naming a formation from its place of minimum exposure was questioned. The faunal and stratigraphic characters were given.

BEARING OF CLINTON AND OSGOOD FORMATIONS ON AGE OF CINCINNATI ANTICLINE

BY AUGUST F. FOERSTE

[*Abstract*]

In continuation of former studies the author developed his interpretation of the Cincinnati anticline. The Devonian axis of the anticline is northeast and southwest, while the topographic axis is north and south. The Clinton strata over the central part of the anticline are coarse lime-sands with wave-marks and cross-bedding, and beds of conglomerates. North and south of this area the material is

a fine lime mud. The paper discussed the relation of these features to those formerly described.

In discussion of the two papers remarks were made by J. M. Clarke, I. C. White, H. M. Ami, B. K. Emerson and the author.

The next paper was

PALEONTOLOGICAL COLLECTIONS OF THE GEOLOGICAL DEPARTMENT OF THE AMERICAN MUSEUM OF NATURAL HISTORY

BY EDMUND OTIS HOVEY

[*Abstract*]

The geological department of the American Museum of Natural History completed in December, 1901, the publication of the catalogue of the type and figured specimens in its possession, by R. P. Whitfield, assisted by the author of the present note. This work has been under way for several years, and in its published form makes up a book of more than five hundred pages, forming volume xi of the Bulletin of the Museum. This is one of the oldest departments of the Museum and its chief possession is the great James Hall collection, which it acquired in 1875, and which placed it at once in the front rank of American museums containing similar material. This collection will always be the standard reference series for all workers in North American Paleozoic paleontology, since it contains a very large proportion of the specimens described and figured by Professor Hall in the course of his work on the "Palæontology of New York" up to the time of its purchase by the American Museum. From time to time the department has received other collections, through exchange and other means, but with the exception of the Holmes collection, they contain few types, aside from such as have been made in the publications of the Museum since their acquisition. Most of the "figured specimens" in the collections of the department are those which were identified, redescribed, illustrated, and published by Professor Hall in the Paleontology of New York, and therefore they have almost the dignity and value of types.

The paper then mentioned in detail the special features of the various portions of the collection, and concluded by saying the catalog had been issued in four parts:

Part I, including the Cambrian and Lower Silurian forms, was issued in July, 1898.

Part II, containing the Upper Silurian specimens, was issued in October, 1899.

Part III, comprising the Devonian forms, came out in October, 1900.

Part IV, listing the specimens from the Lower Carboniferous to the Quaternary, inclusive, and the index, preface, and table of contents of the whole volume, bears date of December 27, 1901.

This work has determined that there are in this department of the Museum at least 6,166 type specimens, representing 2,222 species and 71 varieties, and 2,179 figured specimens, not types, representing 499 species and 119 varieties. Three-fourths of this material has come from the Paleozoic systems above the Cambrian.

The paper will be published in full in the *Journal of Geology*.

The fourth paper was the following:

MESO-CARBONIFEROUS AGE OF THE UNION AND RIVERSDALE FORMATIONS, NOVA SCOTIA

BY H. M. AMI

[*Abstract*]

For many years it was taken for granted that the highly fossiliferous beds of carbonaceous shales, etcetera, known as "the fern ledges" of New Brunswick were of Devonian age, although the character of the flora, even at first sight, is one of decidedly Carboniferous facies. The eighty or more species representing the flora of that period are preeminently Carboniferous, and recently Dr David White has recorded no less than seventeen species of Pottsville forms which came originally from the "fern ledges." The Lancaster formation of the author was defined as that series of strata which held this very characteristic flora, and it is capped by another Carboniferous formation consisting of red shales and conglomerates, with but few species occurring therein; to which formation the designation Mispeck formation of New Brunswick was applied. These two formations, the Lancaster and the Mispeck, find their equivalents in the Union and Riversdale of Nova Scotia, which Sir William Dawson always held to be of Middle Carboniferous age (Middlestone grit).

The main argument advanced by those who held that these four Middle Carboniferous formations were "Devonian" was based on the supposition that the Lower Carboniferous limestones rested unconformably on these same or equivalent formations.

In two of the crucial localities in Nova Scotia visited by the writer some time ago, where Carboniferous shale rested unconformably on shales, etcetera, it has been ascertained beyond a doubt that in one instance (at West bay, near Partridge island and Parrsboro, in Cumberland county, Nova Scotia) the Carboniferous limestone proved, on examination of the organic remains entombed in them, to be of true and undoubted Upper Carboniferous age and not Lower Carboniferous, while in the other instance (in the MacArras Brook region of Nova Scotia, where the "Lower Carboniferous" strata rested unconformably on the so-called "rocks of Union," or Union formation) the writer finds that the subjacent strata are in no sense equivalent to the rocks of the Union formation at all (as they are developed at the type locality near Union station, on the Intercolonial railway, just below Riversdale). The Lower Carboniferous strata at MacArras brook rest unconformably on the upturned edges of the lowest Devonian of that region, as the fossil evidence obtained very clearly showed.* The Knoydart formation of Eo-Devonian age, as seen and developed at MacArras brook, contains a fauna which is so nearly allied and identical with that of the lower "Old Red Sandstone" strata of Scotland and Great Britain generally that the two can very well be classed as homotaxial and belonging to the same period in the history of the earth's crust—an horizon or formation which had not been previously recorded in America, and which nevertheless occupies a definite position, not at the summit of the Devonian, as some geologists would have us believe, but indeed at the very bottom of the system or division of the time-scale.

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*See Bull. Geol. Soc. Am., vol. 12, 1901, pp. 301-312, pl. 26.

The error of correlating the rocks of MacArras brook with those of Union has led to confusion, and the paleontological evidence which has been obtained by the writer in both series of strata has conclusively shown that the one (Knoydart formation) indicates a typical "Old Red Sandstone" fauna that is in lowermost Devonian in age, while the other formation is distinctly referable to the Middle Carboniferous, being associated with and intimately related to the "rocks of Riversdale," containing a typical Meso-Carboniferous flora and fauna, which opinion Messrs R. Kidston, Professor David White, Dr Wheelton Hind, Professor Charles Brongniart, and Dr Henry Woodward and others have shared with the writer. The fact that these "rocks of Union" and the "rocks of Riversdale" had for so many years been referred to the Devonian by Canadian geologists led the writer to seek diligently for Devonian types and forms in those strata, and it must be distinctly stated here that I utterly failed to obtain any horizon markers of Devonian aspect in the true rocks of Union and of Riversdale. All types found were of decidedly Carboniferous facies and well up in that system. The fossil plants, the fossil fishes, the crustacea, the insects, etcetera, all pointed to an horizon of Meso-Carboniferous age, and there we are constrained to place them.

I desire here to correct an error made by myself in following and accepting without verification the statement made by stratigraphical geologists that the "rocks of Union" and the "rocks of Riversdale" were always found overlaid by the marine limestones of the "Lower Carboniferous," and were therefore older. On the contrary, I find that the so-called "rocks of Union," as they are developed at MacArras brook, are the only strata that can in any sense be referred to the Devonian; in which instance it so happens that these so-called "rocks of Union" are not at all the same as those of the Union formation proper. This error on my part in taking for granted that all the strata were one and the same formation, and which had been referred to the "rocks of the Union" and the "rocks of the Riversdale" as unconformably below the limestones of the Lower Carboniferous, as the stratigraphical geologists had said, led me to make the further statement that the "rocks of Union" and the "rocks of Riversdale" were Eo-Carboniferous in age.* In referring these strata to the Carboniferous, I was guided by the fossil remains entombed in them, whereas I was misled by the succession as given by the stratigraphical geologists without any qualifications. It was only when the faunas of the Knoydart formation from the so-called "rocks of Union" in the MacArras Brook region were obtained and determined by Dr A. Smith Woodward and Dr Henry Woodward and others, that the confusion that had existed was evident to me, and the necessity for separating these two sets of strata became apparent. This led to the separation of the Knoydart formations from their supposed equivalents, "the red rocks of Union." I have no hesitation in saying now that the Union and Riversdale formations, as they are developed at the type localities at the Union and Riversdale in Colchester county, in Nova Scotia, are Carboniferous in age, and are Meso-Carboniferous at that. Further, it is also evident that the New Brunswick equivalents of these two formations, namely, the Mispeck and the Lancaster formations (the latter sometimes designated as the Little River group), can not any longer be classed as Devonian, but as truly Meso-Carboniferous formations, with an abundant flora found the world over, and in all countries other than Canada referred to as the Middle Carboniferous.

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*See table of formations in Trans. Nova Scotian Inst. Sci., vol. x, 1900, p. 178.

The main purpose of this paper is to emphasize the fact of the geological investigations made by the writer in the years 1895–1901, during which time he obtained a large assemblage of fossil evidence, both of plants and animals, much of which has been examined by a number of the leading authorities, and their verdict invariably has been in support of the views herein advanced.

The fifth paper of the session, and the last presented by the author in person, was

ORIGIN OF THE LIMESTONE FAUNAS OF THE MARCELLUS SHALES OF NEW YORK

BY JOHN M. CLARKE

[*Abstract*]

The dark Marcellus shales carry a fauna whose members show evidence, both in diminutive form and thin shell, of having been surrounded by conditions which evince a shallow and befouled sea. In the common and historic employment of the term Marcellus shales as an expression of a lithologic unit it has been the usage to include therein such slight variations in sedimentation as these black shales may carry with them. There are in the various sections of these beds two well marked limestone banks—the one, nearer the base, known as the Agoniatites limestone, the other, still higher, as the Stafford limestone. These are persistent over very considerable distances, but the former disappears from the strata where the latter makes its first appearance—that is, about the meridian of Flint creek, Ontario county. In eastern New York the Agoniatites limestone rises to a height above the top of the Onondaga limestone of not less than 40 feet. Going westward, it apparently approaches the horizon of the Onondaga, and where it makes its final appearance as a distinct and identifiable stratum, carrying its characteristic fossils, it is less than 10 feet above the Onondaga. From this point westward its position may be traced by the appearance of its fossils, the index species *Agoniatites expansus* Hall having been found immediately above the summit of the Onondaga limestone at Stony point, south of Buffalo, and actually within the uppermost layers of that limestone at Lime Rock, near Leroy. The fauna of this Agoniatite limestone was evidently an invader from the west, dating from the closing phase of the Onondaga stage. At the time of its appearance the shallow-water Marcellus fauna had invaded the Appalachian gulf from the southeast and had occupied the eastern field for a considerable period. Directly in the train of the Agoniatite fauna followed the prenuncial cohorts of the Hamilton fauna. The Agoniatite fauna held the footing it had gained, while the latter yielded to unfavorable conditions and temporarily retired from the field.

The Stafford limestone lies at an elevation of from 20 to 30 feet above the horizon of the Agoniatite limestone, and its fauna was an assemblage of typical Hamilton species. This was also an invader of later date from the west and the second preliminary appearance of the Hamilton fauna within the confines of New York state. It reached as far eastward as Ontario county, and then retired or was driven to extinction by the continued prevalence of typical Marcellus conditions. This invasion was thus also unsuccessful, but had the fauna dispersed more widely and been able to take and keep possession of the ground which it subsequently acquired, Hamilton time and sedimentation would have been a more important element in the New York succession.

Remarks were made on Dr Clarke's paper by I. C. White, A. P. Brigham, and A. W. Grabau.

In the absence of the authors, the following ten papers were read by title, having been carried to the end of the program under the rule:

NOTES ON MOUNTS HOOD AND ADAMS AND THEIR GLACIERS

BY HARRY FIELDING REID

[*Abstract*]

These two mountains belong to the group of volcanic cones which were built up in Tertiary times along the line of the Cascade range. Though probably extinct, steam and gases still issue in small quantities from cracks at high altitudes. The mountains consist of both lava and lapilli, the latter being more abundant on mount Hood and the former on mount Adams. Some lava flows exist on the slopes of the mountains, whose age is probably not more than a few hundred years. A number of parasitic cones are found on the flanks of mount Adams, two at least with well-marked craters.

Mount Hood has no parasitic cones. About one-half of the original crater wall of Hood still remains, the southern half having disappeared. A rock, known as Crater rock, stands up through the snow in about the center of the original crater. The summit of Adams is long and broad and does not outline a crater. The stratification seen in the cliffs on the sides of the mountain suggests that there were several craters, which may have been active at the same time or successively.

Many interesting glaciers cover the slopes of both mountains, but they are not sunk in valleys. In several cases the depressions outside the lateral moraines are apparently quite as deep as the bed of the glacier, and the canyons formed below the ends of the ice are deeply eroded, in strong contrast to the ice-covered parts of the mountains. It is evident that the main erosion on these mountains has been done by water, and that the ice and snow, by preventing the concentration of the water, have acted rather to prevent erosion.

There is little indication of a much greater extension of the glaciers of Hood in former times, but on Adams glacial scratches abound in positions which could not be reached by the present glaciers except by a very great increase in size.

KEEWATIN AND LAURENTIDE ICE-SHEETS IN MINNESOTA

BY A. H. ELFTMAN

[*Abstract*]

Evidence was presented to show that the glacial drift of the upper Mississippi River valley was deposited by independent lobes of the Keewatin and Laurentide ice-sheets, alternating in their advance and retreat. Minnesota was first invaded by a lobe of the Keewatin ice-sheet. This extended from the northwest to the southeast into Iowa and eastward to Wisconsin, deposited the Kansan and earlier drift-sheets, and formed a glacial lake in the Saint Croix valley north of Taylors falls. The retreat of this ice was followed by a marked interglacial period.

The second great ice invasion, the Iowan, came from the northeast. The Rainy

Lake and Lake Superior lobes of the Laurentide ice-sheet extended to western Minnesota, and the latter lobe was deflected southward into Iowa. This ice does not appear to have retreated beyond the limits of Minnesota., and was followed by a comparatively short interglacial period.

During the third invasion, the Wisconsin, the Minnesota lobe of the Keewatin ice-sheet advanced from the northwest across central Minnesota into Iowa. At the same time the lobes from the Laurentide ice-sheet advanced southwestward until, in several localities, they reached the northeastern limit of the Minnesota lobe. The final retreat of the three lobes was contemporaneous, forming glacial lakes and numerous moraines. A new mapping of the moraines in Minnesota is presented in support of the views advanced. The Rainy Lake lobe was divided into the Red Lake and Leech Lake lobes; the Lake Superior lobe was divided into the Mille Lacs and Saint Croix lobes, and the Minnesota lobe sent a prominent lobe, the Chisago lobe, northeastward to the Saint Croix river.

DEVONIAN INTERVAL IN MISSOURI

BY C. R. KEYES

This paper is printed as pages 267–292 of this volume.

DEVONIAN FISH FAUNA OF IOWA

BY C. R. EASTMAN

[*Abstract*]

During the last four decades important collections of fossil fish remains from the Middle and Upper Devonian of Iowa have been brought together by Messrs O. Saint John, C. A. White, Samuel Calvin and his assistants on the Iowa Geological Survey, C. L. Webster, and others. The greater part of these collections being now deposited in the Museum of Comparative Zoology at Cambridge, exceptional facilities have been enjoyed for investigating the structure and variations of the species represented and for studying the assemblage as a whole in its relations to other faunas. In particular, the Upper Devonian "state quarry fish-bed" discovered by Professor Calvin has yielded rich material for study, the results of which are embodied in this paper. The most general conclusion that can be drawn is that the Hamilton piscine fauna of Wisconsin, Iowa, and Illinois is so closely related to the Corniferous of Ohio and New York as to stamp it as merely a later and western phase of the former, the two together corresponding to the Middle Devonian fish fauna of the Eifel, Bohemia, and Russia. Migrations from the Canadian province on the east do not seem to have taken place until the Chemung epoch, with which the peculiar faunas of the state quarry and Sweetland Creek beds appear to be contemporaneous.

FORMER EXTENT OF THE NEWARK SYSTEM

BY W. H. HOBBS

This paper is printed as pages 139–148 of this volume.

GEOLOGICAL SECTION OF THE ROCKY MOUNTAINS IN NORTHERN ALASKA

BY FRANK C. SCHRADER

This paper is printed as pages 233–252 of this volume.

GEOLOGICAL RECONNAISSANCES IN SOUTHEASTERN ALASKA

BY ALFRED H. BROOKS

This paper is printed as pages 253–266 of this volume.

COPPER-BEARING ROCKS OF VIRGILINA COPPER DISTRICT, VIRGINIA AND NORTH CAROLINA

BY THOMAS L. WATSON

This paper is printed as pages 353–376 of this volume.

CUTTYHUNK ISLAND

BY F. P. GULLIVER

[*Abstract*]

Cuttyhunk island had an initial form of irregularly heaped mounds and kettles characteristic of a terminal moraine. The last movement of the land left several islands, which have since been tied together to form one continuous land-mass. The tombolo at the western end of Cuttyhunk pond is a type example of this class of coastal forms showing early nip now grassed over, cliffs, pebble beach, and a protected harbor now filling up.

MOHOKEA CALDERA ON HAWAII

BY C. H. HITCHCOCK

As the program had been completed during the morning, the Secretary announced appointments for short excursions in the afternoon to the gorge of the Genesee river and to other localities about Rochester.

It was also announced that a reception would be tendered the Society by the president and trustees of the University of Rochester, at the president's house, from 8 to 10 o'clock p m.

The following resolution was offered by Professor B. K. Emerson, and, after remarks by Professor A. P. Coleman, was unanimously adopted :

"*Resolved*, That the Geological Society of America extends its very cordial thanks to the President and Trustees of the University of Rochester and to the authorities of Ward's Natural Science Establishment and to the citizens of Rochester for the hospitality so kindly extended to the Society ; also special thanks to the Professor of Geology of the University, who has added to his duties as our Secretary those of a host."

The Society then adjourned.

Register of the Rochester Meeting, 1901

The following Fellows were in attendance at the meeting:

F. D. Adams.
H. M. Ami.
Florence Bascom.
I. P. Bishop.
A. P. Brigham.
T. C. Chamberlin.
W. B. Clark.
J. M. Clarke.
A. P. Coleman.
W. M. Davis.
R. E. Dodge.
B. K. Emerson.
H. L. Fairchild.
A. F. Foerste.
G. K. Gilbert.
A. C. Gill.
A. W. Grabau.
J. A. Holmes.
T. C. Hopkins.
E. O. Hovey.
J. P. Iddings.
H. B. Kümmel.
A. C. Lane.
F. J. H. Merrill.
F. B. Peck.
W. N. Rice.
I. C. Russell.
W. B. Scott.
J. Stanley-Brown.
J. J. Stevenson.
F. B. Taylor.
C. D. Walcott.
L. G. Westgate.
I. C. White.
H. S. Williams.
Bailey Willis.
N. H. Winchell.
J. E. Wolff.
G. F. Wright.

Total attendance, 39.

Among the visitors were Professor W. G. Miller, School of Mining, Kingston, Ontario; Mr R. W. Brock, of the Geological Survey of Canada, and Professor George H. Perkins, University of Vermont.

Session of the Cordilleran Section, Monday, December 30

The third annual meeting of the Cordilleran Section of the Society was called to order at 10.30 a m, December 30, 1901, in the council-room of the California Academy of Sciences, San Francisco.

In the absence of the Chairman, Professor W. C. Knight, Mr H. W. Turner was elected temporary chairman.

The minutes of the last meeting were read and approved.

The action of the Council of the Society adopting rules and regulations governing the Cordilleran section was reported by the Secretary.

Professor A. C. Lawson was named by the chairman a committee of one to draft suitable resolutions with reference to the death of Professors Joseph Le Conte and E. A. Claypole.

The Section, on motion, instructed the Secretary to send a telegram of greeting to the Geological Society in session at Rochester, New York.

An election for officers for the ensuing year was then held, resulting in the election of Mr H. W. Turner as Chairman of the Section and Mr A. C. Lawson as Secretary.

The Secretary was instructed to prepare a list of members of the Section—that is, of Fellows residing in North America west of the 104th meridian.

An Executive Committee, consisting of the Chairman of the Section, the Secretary, and Professor J. C. Merriam, was appointed to care for the interests of the Section when not in session.

The following papers were then read:

AN INSTANCE OF VARIABILITY IN A ROCK MAGMA

BY H. W. TURNER

Abstract published in *Science*.

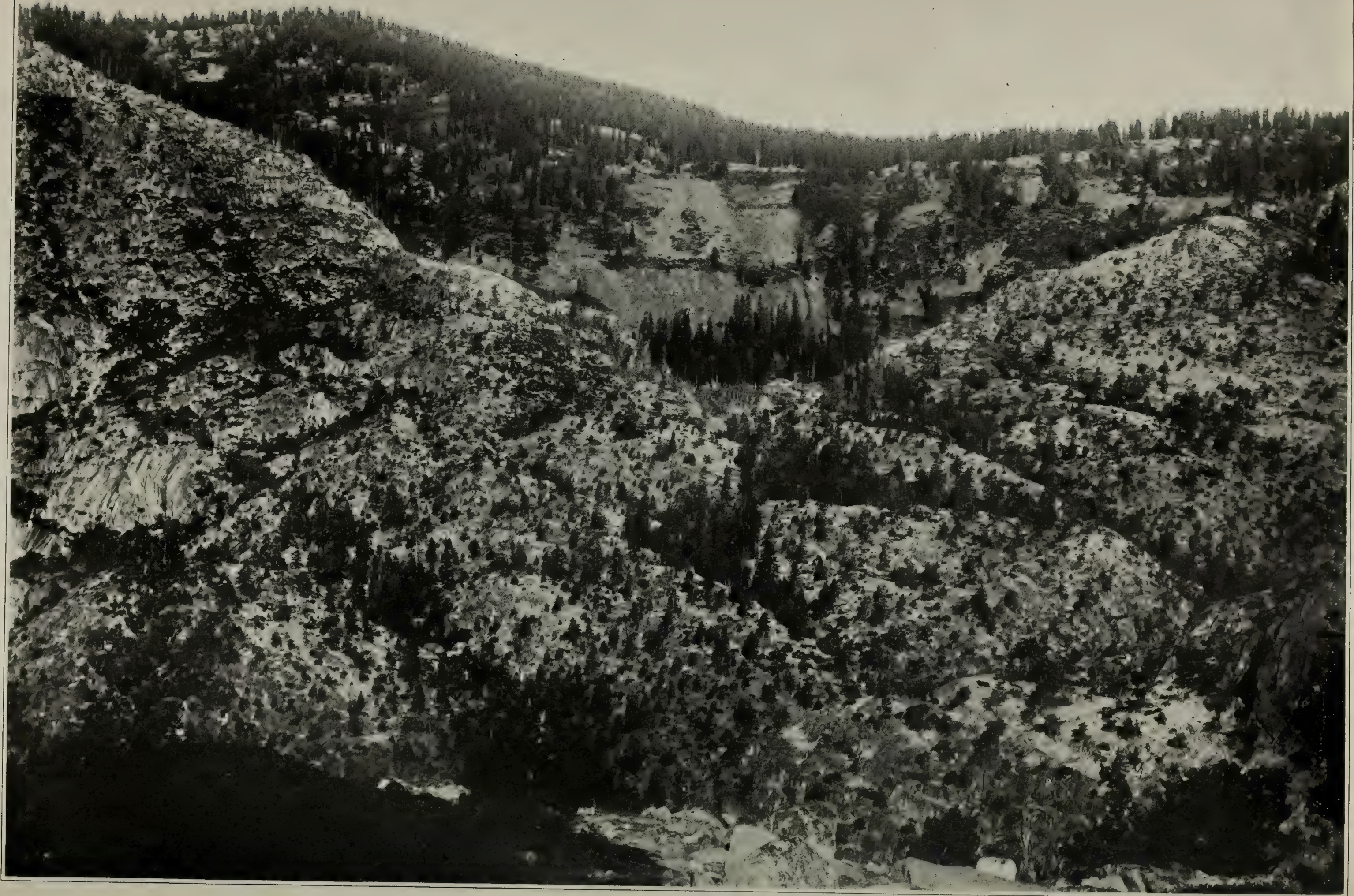
POST-TERTIARY ELEVATION OF THE SIERRA NEVADA

BY H. W. TURNER

In the Yosemite quadrangle only one of the Neocene streams, the Tuolumne, can be traced by its gravels. The reason of this is that only in the Tuolumne basin were there extensive lava flows, which filled the Neocene drainage and preserved the gravels underneath. Even here the gravels and overlying lavas have been largely eroded.

The Neocene channel can be traced from the ridge east of Piute creek, west to the north of Rancheria mountain, thence down Deep canyon, from which point it may have gone down Rancheria creek or over through what is now Tiltill valley, thence over the site of the Hetch Hetchy, reaching the south side of the present Tuolumne canyon to the west of Hog ranch. The bench, with an altitude of about 8,000 feet to the east of Rodgers canyon, pretty certainly represents a portion of the Neocene Tuolumne basin, but except near Rodgers creek the lava covering has been entirely removed.

Going west we find the lava covering well preserved on the spur east of Piute creek, but no gravels are exposed, but the V-shaped channel is clearly evident on the slope toward Piute creek. To the west of this creek is an even better section of a lava-filled, V-shaped channel, and in this case the river gravels are to be seen perhaps 50 feet in thickness at the bottom of the channel. A short tunnel was run in here many years ago, presumably for placer gold in the gravel. Besides abundant lava pebbles, there are numerous pebbles of slate and metamorphic lavas such as make up the mass of mount Dana, and one pebble was found of epidotiferous sandstone, precisely like the rock of the summit of Dana.



SECTION ACROSS BED OF THE NEOCENE TUOLUMNE RIVER, ON WEST SIDE OF PIUTE CANYON

Showing granite river and the lava-filled channel

A view of this cross-section of the old Neocene Tuolumne channel is given on plate 58.

Since between this locality and mount Dana the bed rock series is all granite, it appears probable that in Tertiary time, as now, the Tuolumne river headed near mount Dana. Where Rancheria creek runs through Deep canyon, it has but a slight grade, which is probably nearly the grade of the Neocene Tuolumne, which formerly passed through it. The water for considerable stretches is quite still late in summer, when the flow is small.

Although none of the gravels or the lavas of the Neocene Tuolumne basin are to be found between Rancheria mountain and a point north of Poopenaut valley, nevertheless the approximate course of the channel is not a matter of doubt.

The configuration of the country is such that the river must, as before noted, have either gone down Rancheria creek or over the site of Tiltill valley, thence westward over the site of the Hetch Hetchy. The lava patches on the ridge north of Poopenaut valley are presumed to rest on a portion of the slope of the Neocene Tuolumne basin, and the same is true of the lava area 3 miles west of Poopenaut valley, and the gentle slopes of the ridge in this vicinity are doubtless a portion of the same basin. The next point where the lavas are preserved is about 4 miles westerly from Hog ranch. From there still farther westward there are other lava patches, some of them capping river gravels.

On Rancheria mountain, resting on andesite-tuff, and apparently capped by the compact lava (latite) adjoining, is some gravel containing pebbles of augite-andesite, pegmatite, quartz. This evidently represents a stream of the volcanic period, and later in age than the gravels above described.

The most western point where the gravels of the Neocene Tuolumne have been preserved is east of the head of Big Humbug creek, in the Sonora quadrangle, and the most eastern Piute canyon. If now we calculate the average grade of the Tertiary stream between these two points, and the average grade of the present river between the same points, we can compare the grades of the two streams. The altitude of the Neocene Tuolumne gravels at Big Humbug creek is about 2,800 feet, and at Piute canyon 7,500 feet, giving a difference of 4,700 feet. The altitude of the present Tuolumne north of Big Humbug creek is 1,500 feet, and at Pate valley, at the mouth of Piute creek, 4,550, giving a difference of 3,050 feet. The horizontal distance between the two points is about 33 miles.

Assuming that both the Neocene and the present streams took a direct course, we have a grade of 142 feet to the mile for the Neocene channel and a grade of 92 feet to the mile for the present channel. While the Neocene river occupied a rugged canyon, nevertheless this canyon was much less deep and rugged than that of the present Tuolumne, which implies, other things being equal, a higher grade for the present than for the Neocene channel, while, as we have seen, the reverse is the case. The broad channels and large sand and gravel deposits of the Neocene streams of the Sierra farther north can scarcely be explained on any other hypothesis than of comparatively gentle grades indicating an old age for the streams, and this must have been likewise true of the Neocene Tuolumne, although in less degree.

Assuming that the Neocene Tuolumne had originally a grade at least as low as that of the modern stream, which is evidently yet a young stream, it is clear that the present grade of the Neocene channel must have been brought about by a differential uplift on the east, resulting in a tilting of the range westward.

After discussion of these papers the Section adjourned to meet at the rooms of the Geological Department of the University of California at 2 o'clock p m.

At 2 o'clock p m the Section resumed its session at South Hall, Berkeley, and proceeded with the reading and discussion of the following papers:

TRIASSIC REPTILIA FROM NORTHERN CALIFORNIA

BY JOHN C. MERRIAM

This paper has been published under a different title as Bulletin of the Department of Geology, University of California, volume 3, number 4, pages 63–108. An abstract is printed in *Science*, volume xv, page 411, March 14, 1902.

ORE DEPOSITS OF SHASTA COUNTY, CALIFORNIA

BY F. M. ANDERSON *

Abstract published in *Science.*

LAKE QUIBERIS, AN ANCIENT PLIOCENE LAKE IN ARIZONA

BY W. P. BLAKE *

Abstract published in *Science.*

AN ORBICULAR GABBRO FROM SAN DIEGO, CALIFORNIA

BY ANDREW C. LAWSON

This paper will appear as a bulletin of the Department of Geology, University of California.

The following papers were read by title:

THE EOCENE OF THE HUERFANO BASIN OF COLORADO

BY R. C. HILLS

Abstract published in *Science.*

COAL FIELDS OF SOUTHERN UINTA COUNTY, WYOMING

BY WILBUR C. KNIGHT

[*Abstract*]

The valuable coal fields in southern Uinta county, Wyoming, belong to two distinct and widely separated geological horizons. This section of the state has been rather closely folded, there being no less than three and possibly four anticlinal folds south of the Oregon Short Line railroad and west of the divide between Bear and Green rivers. Prior to the deposition of the Tertiary rocks that cover the greater portion of this region there was a long period of erosion, and these folds were greatly reduced, and in many places all of the Laramie, as well as other lower groups, were removed. In more recent times the present water-courses have uncovered small areas of the Cretaceous rocks, and in many places these are found to be very rich in coal seams. The greatest amount of coal has been found in the Laramie, which has a maximum thickness of about 5,000 feet. The coal veins that are workable are usually inclined from 15 to 40 degrees, and have been mined at the head of Twin creek and Almy. There are twelve known workable veins in this formation that vary in thickness from 5 to 86 feet. There are several that vary from 15 to 30 feet. The 86-foot vein is located at Adaville, about 4 miles west of Kemmerer, and was opened up by a foreign company, but did not furnish fuel for the trade. This vein is most remarkable for its immensity and unusual purity. While I have examined a cross-cut made through the vein, I did not measure it, but believe that the engineer that gave me the figures was reliable. The coal is a medium grade lignite, and in examining it in the cross-cut tunnel I found it solid coal with the exception of a very thin band of sandstone which was less than an inch in thickness.

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* Presented by A. C. Lawson.

All of the Laramie coals are lignites; but they vary greatly in composition. The mines at Almy have produced a very desirable locomotive fuel for a period of thirty years. Typical outcrops of the Laramie can be seen at Almy, Twin creek, and at the head of Muddy creek.

Below the Laramie there is a very thick bed of shale containing a few bands of sandstone. The shales vary from a drab to a gray color, and west of Kemmerer have a thickness of about 5,000 feet. This formation can be traced south to Hilliard, where it has about the same lithological characteristics and thickness. In the Survey of the Fortieth Parallel this formation was given a questionable place, but mentioned as being above the supposed Fox hills. Since there is no formation corresponding to this shale bed that I am familiar with in the state, I propose the name Hilliard for this horizon, the name being derived from the town of Hilliard, which is located on these beds of shale, and cite the shale beds west of Kemmerer and extending as far as the east portal of the Oregon Short Line tunnel as a typical section. There are some associated fossils with these shales, but typical ones cannot be given at this time.

Below the Hilliard formation there is a second and very important coal-bearing formation, but one that has but recently been discovered. This extends from Kemmerer southward passing through Diamondville, Cumberland, Spring Valley, and just east of Hilliard, and is composed of very thick beds of compact sandstone, with shales and coals having an approximate thickness of 2,000 feet. This has been called Fox hills, but upon making a careful examination I could not find a Fox Hill fauna such as is common to the Fox hills of the eastern part of Wyoming. On this account I have found it advisable to call these beds the Frontier formation, the name being derived from the town of Frontier, just north of Kemmerer. This formation is characterized by the presence of *Ostrea soleniscus*, which has a maximum length of about 12 inches, and so far as I am aware occurs only in this formation. In the Frontier there are several seams of coal varying in thickness from 4 to 20 feet, and mines are being operated at Frontier, Diamondville, Cumberland, and Spring Valley town. The coal is a superior bituminous fuel, being quite hard, with little water and ash, and from tests made with a bom calorimeter is the best steaming coal discovered in Wyoming. This formation has never been found east of Cumberland, and there are but few exposures west of that place where coal has been discovered. When the territory has been thoroughly prospected the greater part of the Coal Measures of Uinta county will be found to be in the Frontier formation. On account of the superiority of the fuel, the Frontier coal fields are being eagerly sought for and will be exhausted long before they pay any attention to the Laramie lignites. The following are typical analyses:

LARAMIE COAL.	Water.	Volatile matter.	Fixed carbon.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Almy	7.38	34.88	48.75	9.00
Red canyon	7.42	36.08	48.50	8.00
Twin creek	8.[illegible]8	35.32	49.90	6.30
Hams fork	15.64	49.30	38.97	3.21
FRONTIER COAL.				
Diamondville (selected)	3.53	48.58	51.36	1.53
Kemmerer (selected)	2.00	39.10	55.85	3 05
Diamondville	3.90	38.05	53.55	4.50
Kemmerer	2.95	38.00	54.00	4.05

DEBRIS FANS OF THE ARID REGION IN THEIR RELATION TO WATER SUPPLY

BY E. W. HILGARD

Abstract published in *Science*.

The Section then adjourned, to meet at 10 o'clock next morning.

SESSION OF THE CORDILLERAN SECTION, TUESDAY, DECEMBER 31

The Section met at 10 o'clock a m, in the rooms of the Geological Department of the University of California, the Chairman, Mr H. W. Turner, in the chair.

The following papers were read and discussed:

LAKE CHELAN, WASHINGTON

BY H. W. FAIRBANKS

Abstract published in *Science*.

GEOLOGICAL SECTION OF THE MIDDLE COAST RANGES OF CALIFORNIA

BY ANDREW C. LAWSON

[*Abstract*]

The paper is an attempt to summarize recently acquired information as to the sequence of formations and their respective volumes of sediments in the Middle Coast ranges of California. The results given for the thickness are approximations sufficiently close to afford a general idea of the section. Other features of the paper are the subdivision of the Franciscan into seven stratigraphic subdivisions by the recognition of a persistent horizon of foraminiferal limestone and two important horizons of radiolarian chert; a similar subdivision of the Monterey into seven stages and a summary announcement of the character and history of the post-Monterey Tertiary. The essential features of the paper are given in the following tabulation:

Geological Section of the Coast Ranges of California in the Vicinity of the Bay of San Francisco

			Thickness Feet
Merced		Upper marine sandstones, sandy shales, and clay shales	5,830
		Lower marine clays, sandy shales, sandstones, fine pebbly conglomerates	
Unconformity.			
Campan		Volcanics, andesites, basalts, rhyolite agglomerates	500
		Fresh-water conglomerates, sandstones, clays, limestones	
Unconformity.			
U. Berkeleyan		Volcanics, basalts, and tuffs	200
		Siestan, fresh-water clays, limestones, sandstones, shales, lignite, tuffs, conglomerates	
		Volcanics, andesites, basalts, rhyolite tuffs	
Unconformity.			
L. Berkeleyan		Volcanics, andesites, basalts, rhyolite tuffs	2,000
		Trampan, marine shales, sandstones, pebbly conglomerates	
		Orindan, fresh-water conglomrates, sandstones, clays, limestones, tuffs	2,400
Pinole—Tuffs (pumiceous) fossiliferous			1,000
San Pablo—Blue tuffaceous sandstone, marine			1,500
Unconformity.			
Monterey	Upper	Stage 7—Sandstone	1,800
	Middle	Stage 6—Bituminous shale	670
		Stage 5—Sandstone	1,200
		Stage 4—Bituminous shale	460
		Stage 3—Sandstone	600
		Stage 2—Bituminous shale and chert	250
	Lower	Stage 1—Sandstone	400
Unconformity.			
Karquinez		Tejon—Massive sandstones	2,100
		Martinez—Massive sandstones	2,200
		Rhyolite flows. (Age not certainly determined.)	
Unconformity.			
Shasta-Chico		Chico—Sandstones and shales	3,000+
		Oakland—Conglomerate	500
		Peridotite irruptions.	
		Knoxville—Shales with subordinate limestone and conglomerate	1,000
Unconformity. Volcanics.			
Franciscan		Bonita sandstone	1,400
		San Miguel cherts, radiolarian	530
		Marine sandstone	1,000
		Sausalito cherts, radiolarian	900
		Bolinas sandstone (volcanics)	2,000
		Volcanics.	
		Calera limestone, foraminiferal	60
		Volcanics.	
		Pilarcitos sandstone	790
			34,290

Unconformity.
Montara granite (correlated tentatively with late Jurassic granite of Sierra Nevada).

The Section then adjourned for luncheon.

At 2 o'clock p m the Section resumed its session at South hall, Berkeley.

The following resolution was adopted:

The Fellows of the Cordilleran Section of the Geological Society of America desire to express and to place on record their profound sorrow and sense of loss in the death of their esteemed fellow-members, Professor Joseph Le Conte, who died at Yosemite valley on July 6, 1901, and Professor E. W. Claypole, who died at Pasadena August 17, 1901.

The following papers were then read and discussed:

A CONTRIBUTION TO THE PETROGRAPHY OF THE JOHN DAY BASIN

BY FRANK C. CALKINS*

This paper has been published as Bulletin of the Department of Geology, University of California, volume 3, number 5, pages 109–172.

COLEMANITE

BY A. S. EAKLE

This paper has been published as Bulletin of the Department of Geology, University of California, volume 3, number 2, pages 31–50.

THE MARINE PLIOCENE AND PLEISTOCENE STRATIGRAPHY OF THE COAST OF SOUTHERN CALIFORNIA

BY DELOS ARNOLD AND RALPH ARNOLD*

This paper has been published in the Journal of Geology, volume x, number 2.

The Section then adjourned.

Andrew C. Lawson, *Secretary.*

Register of San Francisco Meeting of Cordilleran Section, 1902

The following is the register of the Fellows present at the meeting:

A. S. Eakle.
H. W. Fairbanks.
J. C. Merriam.
A. C. Lawson.
W. J. Sutton.
H. W. Turner.

Fellows-elect

F. M. Anderson.
G. D. Louderback.

The visitors were

Miss A. Alexander.
F. C. Calkins.
V. C. Osmont.
J. W. Sinclair.
G. J. Young.

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* Presented by Professor J. C. Merriam.

ACCESSIONS TO LIBRARY FROM JUNE, 1901, TO JUNE, 1902

BY H. P. CUSHING, *Librarian*

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(*A*) FROM SOCIETIES AND INSTITUTIONS RECEIVING THE BULLETIN AS DONATION ("EXCHANGES")

(*a*) *AMERICA*

NEW YORK STATE MUSEUM, ALBANY

2153–2155. Bulletins, vols. 1–3, nos. 1–15.
2156, 2157. Annual Report, no. 53, parts i and ii, 1899.

BOSTON SOCIETY OF NATURAL HISTORY, BOSTON

1700. Proceedings, vol. 29, nos. 17, 18, 1901.
2133. " " 30, nos. 1–3, 1901–'02.

MUSEO NACIONAL DE BUENOS AIRES, BUENOS AIRES

1539. Communicaciones, tomo 1, nos. 8, 9.

CHICAGO ACADEMY OF SCIENCES, CHICAGO

834. Bulletin, vol. ii, no. 4, 1901.

FIELD COLUMBIAN MUSEUM, CHICAGO

1988. Publication 57, Zoological Series, vol. ii, no. 2.
1916. Publications 58, 59, Zoological Series, vol. iii, nos. 4, 5.
1000. " 60 and 63, Geological Series, vol. i, nos. 9, 10.
2181. Publication 62, Report Series, vol. ii, no. 1.

CINCINNATI SOCIETY OF NATURAL HISTORY, CINCINNATI

2149. Journal, vol. xx, nos. 1, 2, 1901.

COLORADO SCIENTIFIC SOCIETY, DENVER

1990. Proceedings, vol. vii, pp. 37–40.

NOVA SCOTIAN INSTITUTE OF SCIENCE, HALIFAX

MUSEO DE LA PLATA, LA PLATA

INSTITUTO GEOLOGICO DE MEXICO, MEXICO

1981. Boletin num. 15, Las Rhyolitas de Mexico, part ii, 1901.

NATURAL HISTORY SOCIETY, MONTREAL

1946. Canadian Record of Science, vol. viii, nos. 6–7, 1901.

AMERICAN GEOGRAPHICAL SOCIETY, NEW YORK

1992. Bulletin, vol. xxxiii, nos. 2–5, 1901.
2172. “ “ xxxiv, nos. 1–2, 1902.

AMERICAN MUSEUM OF NATURAL HISTORY, NEW YORK

1647. Annual Report of the President, etc., 1900.
1507. Bulletin, vol. xi, part 4, 1901.
2144. “ “ xiv, 1901.
2145. “ “ xv, part 1, 1901.
2150. “ “ xvii, part 1, 1902.

NEW YORK ACADEMY OF SCIENCES, NEW YORK

2083. Annals, vol. xiv, part 1, 1901.

GEOLOGICAL SURVEY OF CANADA, OTTAWA

2079. Annual Report, new series, vol. xi, 1898, with maps.
2124. Catalogue of Canadian Birds, part i, 1900.
2139. Index to Reports, 1863–1884, 1900.

ROYAL SOCIETY OF CANADA, OTTAWA

2160. Proceedings, second series, vol. vi, 1900.

ACADEMY OF NATURAL SCIENCES, PHILADELPHIA

2010. Proceedings, vol. liii, parts 1–3, 1901.

AMERICAN PHILOSOPHICAL SOCIETY, PHILADELPHIA

2054. Proceedings, vol. xl, nos. 165–167, 1901.
2174. Transactions, vol. xx, new series, parts 1–2.

MUSEO NACIONAL DE RIO DE JANEIRO, RIO DE JANEIRO

CALIFORNIA ACADEMY OF SCIENCES, SAN FRANCISCO

GEOLOGICAL SURVEY OF NEWFOUNDLAND, ST JOHNS

ACADEMY OF SCIENCE, ST LOUIS

2009. Transactions, vol. xi, nos. 4–11, 1901.
2163. “ “ xii, nos. 1–4, 1902.

COMMISSAO GEOGRAPHICO E GEOLOGICO, SAO PAULO

NATIONAL GEOGRAPHIC SOCIETY, WASHINGTON

724. National Geographic Magazine, vol. iii, pp. 31–52, 205–261.
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2136. " " " " xiii, nos. 1–5, 1902.

LIBRARY OF CONGRESS, WASHINGTON

SMITHSONIAN INSTITUTION, WASHINGTON

2049. Annual Report, 1899.

UNITED STATES GEOLOGICAL SURVEY, WASHINGTON

2089–2091. Twenty-first Annual Report, parts 1, 6, and 6 continued.
2158. Monograph xl.
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2159–2161. Bulletins 178, 180–181, 183–187.
2195-2197. Twenty-first Annual Report, parts 2–4.

UNITED STATES NATIONAL MUSEUM, WASHINGTON

(b) *EUROPE*

DEUTSCHE GEOLOGISCHE GESELLSCHAFT, BERLIN

1917. Zeitschrift, band lii, heft 4, 1900.
2087. " " liii, heft 1–3, 1901.

KÖNIGLICH PREUSSISCHEN GEOLOGISCHEN LANDESANSTALT UND BERGAKADEMIE, BERLIN

2055. Jahrbuch, band xx, 1899.

GEOGRAPHISCHEN GESELLSCHAFT, BERNE

R. ACCADEMIA DELLE SCIENZE DELL' INSTITUTO DI BOLOGNA, BOLOGNA

ACADÊMIE ROYALE DE BELGIQUE, BRUSSELS

SOCIÉTÉ BELGE DE GÉOLOGIE, DE PALEONTOLOGIE ET D'HYDROLOGIE, BRUSSELS

1697. Bulletin, tome xii, fasc. 3–4, 1897.
2006. " " xv, fasc. 2–6, 1901.
2192. " " xvi, fasc. 1, 1902.

BIUROULI GEOLOGICA, BUCHAREST

MAGYARHONI FÖLDTANI TARSULAT, BUDAPEST

1940. Földtani Közlöny, xxx kötet, 10–12 fuset, 1900.
2060. " " xxxi, kötet, 1–9 fuset, 1901.

NORGES GEOLOGISKA UNDERSOGELSE, CHRISTIANA

2056–2059. Nos. 18–21, 1895–'96.
2061–2068. Nos. 22–29, 1897–1900.
2068. Nos. 30 and 32.
2179. No. 31.

DANMARKS GEOLOGISKA UNDERSOGELSE, COPENHAGEN

ACADÉMIE ROYALE DES SCIENCES ET DES LETTRES DE DANEMARK, COPENHAGEN

2003. Oversigt i Aaret, 1901, nr. 2–6.

NATURWISSENSCHAFTLICHEN GESELLSCHAFT ISIS, DRESDEN

2135. Sitzungsberichte und Abhandlungen, Jahrgang, 1901.

ROYAL SOCIETY OF EDINBURGH, EDINBURGH

NATURFORSCHENDEN GESELLSCHAFT, FREIBURG, I. B.

1707. Berichte, band xi, heft 3, 1901.

GEOLOGICAL SOCIETY OF GLASGOW, GLASGOW

PETERMANN'S GEOGRAPHISCHE MITTHEILUNGEN, GOTHA

KSL. LEOP. CAROL. DEUTSCHEN AKADEMIE DER NATURFORSCHER, HALLE

2092. Nova Acta, Abhandlungen, band 77, 1901.
2107. “ “ “ band 78, 1901.
2167. “ “ “ band 79, 1902.
2109–2119. Leopoldina, heft 2–12.
2094–2104. “ “ 13–23.
2105–2106. “ “ 24–25.
2125–2131. “ “ 26–32.
2108. “ “ 36.
2121–2122. Reportorium, heft i–ii.
2093. Geschichte, 1888–1900.
2120. “ 1852–1887.

GEOLOGISKA UNDERSOKNING, HELSINGFORS

1126. Beskrifning till Kartbladet, nos. 36–37, 1901.

SOCIÉTÉ DE GÉOGRAPHIE DE FINLANDE, HELSINGFORS

2182–2184. Bulletins, Fennia, 10, 16, and 18, 1901.

SOCIÉTÉ GÉOLOGIQUE SUISSE, LAUSANNE

GEOLOGISCH REICHS-MUSEUM, LEIDEN

1710. Sammlungen, band vi, heft 3–4, 1900.
2070–2073. “ “ i-iv, 1881–'90.
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KON.-SÄCHISCHE GESELLSCHAFT DER WISSENSCHAFTEN, LEIPZIG

322. Abhandlungen der Math.-Phys. Classe, band xviii, heft 1, 1891.
1340. “ “ “ “ “ “ xxiv, heft 6, 1899.
1768. “ “ “ “ “ “ xxvi, heft 5–7, 1901.
2189. “ “ “ “ “ “ xxvii, heft 1–3, 1902.

1774. Berichte über die Verhandlungen, Math.-Phys. Classe, Jahrgang 1900, heft 4.
2080. Berichte über die Verhandlungen, Math.-Phys. Classe, Jahrgang 1901, heft 1-6.

SOCIÉTÉ GÉOLOGIQUE DE BELGIQUE, LIEGE

2008. Annales, tome xxviii, livr. 3-4, 1901.
2193. " " xxix, livr. 1, 1902.

SOCIÉTÉ GÉOLOGIQUE DU NORD, LILLE

2088. Annales, tome xxix, 1900.

COMMISSAO DOS SERVICOS GEOLOGICOS DE PORTUGAL, LISBON

2185. Communicacoes, tomo iv, 1900-'01.

BRITISH MUSEUM (NATURAL HISTORY), LONDON

2191. Catalogue of the Fossil Fishes in the British Museum, part 4.

GEOLOGICAL SOCIETY, LONDON

1679. Geological Literature, 7.
1976. Quarterly Journal, vol. lvii, part 3, 1901.
2162. " " " lviii, parts 1-2, nos. 229, 230, 1902.

GEOLOGICAL SURVEY, LONDON

GEOLOGISTS' ASSOCIATION, LONDON

2002. Proceedings, vol. xvii, parts 1-5, 1901.
284. " " xii, parts 1-5, 1892.

COMISION DEL MAPA GEOLOGICA DE ESPANA, MADRID

SOCIETÀ ITALIANA DI SCIENZE NATURALI, MILAN

2051. Atti, vol. xl, fasc. 1-4, 1901.
2198. " " xli, fasc. 1, 1902.
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SOCIÉTÉ IMPERIALE DES NATURALISTES DE MOSCOU, MOSCOW

1999. Bulletin, Année 1900, nos. 3-4.
2173. " " 1901, nos. 1-2.

K. BAYERISCHE AKADEMIE DER WISSENSCHAFTEN, MUNICH

1965. Sitzungsberichte, 1900, heft 3.
2141. " 1901, heft 1-3.
2142. Inhaltsverzeichniss der Sitzungsberichte, 1886-1899.
2143. Ziele und Aufgabe der Akademien im zwanzigsten Jahrhundert.

RADCLIFFE LIBRARY, OXFORD UNIVERSITY MUSEUM, OXFORD

2046. Catalogue of books added during 1900.

ANNALES DES MINES, PARIS

1985. Annales, tome xix, livr. 2–6, 1901.
2084. " " xx, livr. 7–12, 1901.
2188. " dixieme serie, tome i, livr. 1–2, 1902.

CARTE GÉOLOGIQUE DE FRANCE, PARIS

1791. Bulletin, vol. xi, nos. 71–78, 1900–'01.
2190. " " xii, nos. 79–82, 1901–'02.

SOCIÉTÉ GÉOLOGIQUE DE FRANCE, PARIS

1680. Bulletin, 3^e^ serie, tome xxvii, no. 6, 1899.
1907. " " " tome xxviii, no. 8, 1900.
2052. " 4^e^ serie, tome i, nos. 1–4, 1901.
2194. " " " tome ii, no. 1, 1902.

REALE COMITATO GEOLOGICO D'ITALIA, ROME

2053. Bolletino, vol. xxxii, n. 1–4, 1901.

SOCIETA GEOLOGICA ITALIANA, ROME

ACADÉMIE IMPERIALE DES SCIENCES, ST PETERSBURG

COMITÉ GÉOLOGIQUE DE LA RUSSIE, ST PETERSBURG

384. Memoirs, vol. xiii, no. 3, 1901.
2176. " " xviii, nos. 1–2.
2069. Bulletin xix, nos. 1–10, 1900.
2177. " xx, nos. 1–6, 1901.
2178. Bibliotheque, Geologie de la Russie, 1897.

RÜSSISCH-KAISERLICHEN MINERALOGISCHEN GESELLSCHAFT, ST PETERSBURG

2000. Verhandlungen, zweite serie, band xxxviii, lief. 2.
2175. " " " " xxxix, lief. 1.

GEOLOGISKA BYRAN, STOCKHOLM

GEOLOGISKA FÖRENINGENS, STOCKHOLM

1977. Förhandlingar, band xxiii, häfte 4–7, 1902.
2161. " " xxiv, häfte 1–4, 1902.

NEUES JAHRBUCH FÜR MINERALOGIE, STUTTGART

1966. Neues Jahrbuch, Jahrgang 1901, band i, heft 2–3.
2133. " " " 1901, band ii, heft 1–3.
2165. " " " 1902, band i, heft 1–2.
1987. Centralblatt, 1901, nos. 3–24.
2164. " 1902, nos. 1–4.

KAISERLICH-KÖNIGLICHEN GEOLOGISCHEN REICHANSTALT, VIENNA

2045. Jahrbuch, band 1, heft 1–4, 1900.

KAIS.-KÖNIGLICHEN NATURHISTORISCHEN HOFMUSEUMS, VIENNA

1942. Annalen, band xv, nr. 2, 1900.

DIE BIBLIOTHEK DES EIDG. POLYTECHNICUMS, ZURICH

(*c*) *ASIA*

GEOLOGICAL SURVEY OF INDIA, CALCUTTA

1517. General Report of the Work carried on in 1900–'01.
1931. Memoirs, vol. xxx, parts 2–4, 1901.
2132. " vol. xxxi, parts 1–3, 1901.
2137. " vol. xxxii, parts 1–2, 1901.
2001. " vol. xxxiii, part 2, 1901.
2186. " vol. xxxiv, part 1, 1901.

IMPERIAL GEOLOGICAL SURVEY, TOKIO

1209. Geological Map of Japan, 9 atlas sheets with descriptive pamphlets, and 3 topographic sheets.

(*d*) *AUSTRALASIA*

GEOLOGICAL DEPARTMENT OF SOUTH AUSTRALIA, ADELAIDE

1515. Record of the Mines, Exploration of the Tarcoola District.
2140. Handbook of Mining, with maps, 1901.

GEOLOGICAL SURVEY OF QUEENSLAND, BRISBANE

2169. Annual Progress Reports, 1896–1900.
2170. Nine Separate Reports on Mining Districts.
2171. Ten " " " " "
1589. Bulletins, nos. 11–17.

CANTERBURY MUSEUM, CHRISTCHURCH

DEPARTMENT OF MINES OF VICTORIA, MELBOURNE

2077. Report on Little Bendigo Gold Field, Ballarat, 1901.
2078. Annual Report of the Secretary of Mines for 1900.
2151. Underground Survey of Mines, Bendigo Gold Field.
2152. Report on the Walhalla Gold Field.

GEOLOGICAL DEPARTMENT OF WESTERN AUSTRALIA, PERTH

2138. Annual Report of Progress for 1900.

GEOLOGICAL SURVEY OF NEW SOUTH WALES, SYDNEY

2043. Annual Mining Report of the Department for the Year 1899.
2044. Records of the Geological Survey, vol. vii, part 1, 1901.
2050. The Mineral Resources of New South Wales.
2076. Memoirs, Geology no. 2, Iron Ore Deposits of N. S. W.
2148. Annual Report of the Department of Mines for 1900.
2168. Mineral Resources, nos. 9–10.

ROYAL SOCIETY OF NEW SOUTH WALES, SYDNEY

2085. Journal and Proceedings, vol. xxxiv, 1900.

(e) *AFRICA*

GEOLOGICAL COMMISSION, CAPE TOWN

2146–2147. Annual Reports for 1898 and 1899.

(*B*) From State Geological Surveys and Mining Bureaus

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA, MINNEAPOLIS

2048. Final Report, vol. vi.

GEOLOGICAL SURVEY OF NEW JERSEY, TRENTON

2200. Annual Report of the State Geologist for the Year 1900.

(*C*) From Scientific Societies and Institutions

GEOLOGISCHEN KOMMISSION DER SCHWEIZ.-NATURFORSCHENDEN GESELLSCHAFT, BERNE

2166. Beitrage zur Geologischen Karte der Schweiz, lief. xi, 1901.

NATURHISTORISCHEN VEREINS DER PREUSSISCHEN RHEINLANDE, WESTFALENS, ETC., BONN

2201. Verhandlungen, Jahrgang lxxv, 1900.

NIEDERRHEINISCHEN GESELLSCHAFT FUR NATUR- UND HEILKUNDE ZU BONN, BONN

2202. Sitzungsberichte, 1900.

SCHLESISCHE GESELLSCHAFT FÜR VATERLÄNDISCHE CULTUR, BRESLAU

2134. Achtundsiebzigster Jahres-bericht, 1900.

ACADÉMIE ROYALE DES SCIENCES, DES LETTRES ET DES BEAUX-ARTS DE BELGIQUE, BRUSSELS

2082. Annuaire, soixante-septieme Annéè, 1901.

GEOLOGICAL SURVEY OF BRITISH GUIANA, DEMERARA

2187. Three geologic maps, with explanatory texts.

SOCIEDAD CIENTIFICA "ANTONIO ALZATE," MEXICO

2203. Memorias y Revista, tomo xiii, nums. 1–3, 1901.
2204. " " " " xvi, nums. 1–3, 1901–'02.

GEOLOGICAL SURVEY OF NATAL AND ZULULAND, PIETERMARITZBURG

2180. First Report of the Survey, 1901.

SECTION GÉOLOGIQUE DU CABINET DE SA MAJESTÈ, ST PETERSBURG

1604. Travaux, vol. iii, livr. 2, 1901.
2205. " " iv, 1901.

IMPERIAL UNIVERSITY OF TOKYO, COLLEGE OF SCIENCE, TOKIO

2206. Journal, vol. xvi, part 1.

TOKYO GEOGRAPHICAL SOCIETY, TOKIO

2207. Journal of Geography, vol. xiii, nos. 145-156, 1901.

(*D*) FROM FELLOWS OF THE GEOLOGICAL SOCIETY OF AMERICA (PERSONAL PUBLICATIONS)

H. L. FAIRCHILD

2208. Beach Structure in Medina Sandstone.

C. H. HITCHCOCK

2209. New Zealand in the Ice Age.

GEORGE P. MERRILL

2210. Stony Meteorite which fell near Felix, Perry County, Alabama.

JOSEPH HYDE PRATT

2211. Eight separates, extracts from Mineral Resources of the United States for 1900.

HENRY S. WASHINGTON

2212. Igneous Rocks from eastern Siberia.
2213. The Foyaite-Ijolite Series of Magnet Cove.

(*E*) FROM MISCELLANEOUS SOURCES

COMMISSIONERS OF THE STATE RESERVATION AT NIAGARA, ALBANY

2214. Seventeenth Annual Report, 1899–1900.

UNIVERSITY OF TEXAS, AUSTIN

2215. Mineral Survey Bulletin no. 1, Texas Petroleum.

BROOKLYN INSTITUTE OF ARTS AND SCIENCES, BROOKLYN

2216. Science Bulletin, vol. i, no. 1, 1901.

CINCINNATI MUSEUM ASSOCIATION, CINCINNATI

2217. Twentieth Annual Report, 1900.

GEOGRAPHICAL SOCIETY OF PHILADELPHIA, PHILADELPHIA

2218. Bulletin, vol. iii, nos. 1–2, 1901.

PORTLAND SOCIETY OF NATURAL HISTORY, PORTLAND, ME.

2219. Proceedings, vol. ii, part 5, 1901.

THE MAZAMAS, PORTLAND, OREG.

2220. Mazama, vol. ii, no. 1, 1900.

REV H. E. HAYDEN

2221. Ralph Dupuy Lacoe

K. MARTIN

2222. Reise-Ergebnisse aus den Molukken.

FERDINAND VON RICHTHOFEN

2223. Geomorphologische Studien aus Ostasien.

B. E. WALKER

2224. List of the published Writings of Elkanah Billings.

OFFICERS AND FELLOWS OF THE GEOLOGICAL SOCIETY OF AMERICA

OFFICERS FOR 1902

President

N. H. Winchell, Minneapolis, Minn.

Vice-Presidents

S. F. Emmons, Washington, D. C.
J. C. Branner, Stanford University, Cal.

Secretary

H. L. Fairchild, Rochester, N. Y.

Treasurer

I. C. White, Morgantown, W. Va.

Editor

J. Stanley-Brown, Washington, D. C.

Librarian

H. P. Cushing, Cleveland, Ohio

Councillors

(Term expires 1902)

W. B. Clark, Baltimore, Md.
A. C. Lawson, Berkeley, Cal.

(Term expires 1903)

Samuel Calvin, Iowa City, Iowa
A. P. Coleman, Toronto, Canada.

(Term expires 1904)

C. W. Hayes, Washington, D. C.
J. P. Iddings, Chicago, Ill.

FELLOWS, AS OF JANUARY, 1903

* Indicates Original Fellow (see article III of Constitution)

Cleveland Abbe, Jr., Ph. D., 2017 I St. N. W., Washington, D. C. August, 1899.

Frank Dawson Adams, Ph. D., Montreal, Canada ; Professor of Geology in McGill University. December, 1889.

George I. Adams, Sc. D., U. S. Geological Survey, Washington, D. C. Dec., 1902.

José Guadalupe Aguilera, Esquela N. de Ingeneiros, City of Mexico, Mexico ; Director del Instituto Geologico de Mexico. August, 1896.

Truman H. Aldrich, M. E., Birmingham, Ala. May, 1889.

Henry M. Ami, A. M., Geological Survey Office, Ottawa, Canada ; Assistant Paleontologist on Geological and Natural History Survey of Canada. December, 1889.

Frank M. Anderson, B. A., M. S., 2435 Piedmont Ave., Berkeley, Cal. In California State Mining Bureau. June, 1902.

Philip Argall, 821 Equitable Building, Denver, Colo. ; Mining Eng. August, 1896.

George Hall Ashley, M. E., Ph. D., Charleston, S. C. ; Professor of Natural History, College of Charleston. August, 1895.

Harry Foster Bain, M. S., Quadrangle Club, 58th St., Chicago, Ill. Dec., 1895.

Rufus Mather Bagg, Ph. D., 84 Ellis St., Brockton, Mass. December, 1896.

S. Prentiss Baldwin, 736 Prospect St., Cleveland Ohio. August, 1895.

Erwin Hinckley Barbour, Ph. D., Lincoln, Neb. ; Professor of Geology, University of Nebraska, and Acting State Geologist. December, 1896.

Joseph Barrell, Ph D., South Bethlehem, Pa. ; Assistant Professor of Geology, Lehigh University. December, 1902.

George H. Barton, B. S., Boston, Mass. ; Instructor in Geology in Massachusetts Institute of Technology. August, 1890.

Florence Bascom, Ph. D., Bryn Mawr, Pa. ; Instructor in Geology, Petrography, and Mineralogy in Bryn Mawr College. August, 1894.

William S. Bayley, Ph. D., Waterville, Me. ; Professor of Geology in Colby University. December, 1888.

*George F. Becker, Ph. D., Washington, D. C. ; U. S. Geological Survey.

Charles E. Beecher, Ph. D., Yale University, New Haven, Conn. May, 1889.

Joshua W. Reese, Ph. D., Bloomington, Ind. ; Instructor in Geology, Indiana University. December, 1902.

Robert Bell, C. E., M. D., LL. D., Ottawa, Canada ; Assistant Director of the Geological and Natural History Survey of Canada. May, 1889.

Charles P. Berkey, Ph. D., Minneapolis, Minn. ; Instructor in Mineralogy, University of Minnesota. August, 1901.

Samuel Walker Beyer, Ph. D., Ames, Iowa ; Assistant Professor in Geology, Iowa Agricultural College. December, 1896.

Albert S. Bickmore, Ph. D., American Museum of Natural History, New York ; Professor in charge of Department of Public Instruction. December, 1889.

Irving P. Bishop, 109 Norwood Ave., Buffalo, N. Y. ; Professor of Natural Science, State Normal and Training School. December, 1899.

Emilio Böse, Ph. D., Calle del Paseo Nuevo, no. 2, Mexico, D. F. ; Geologist of the Instituto Geologico de Mexico. December, 1899.

*John C. Branner, Ph. D., Stanford University, Cal. ; Professor of Geology in Leland Stanford, Jr., University.

Albert Perry Brigham, A. B., A M., Hamilton, N. Y. ; Professor of Geology and Natural History, Colgate University. December, 1893.

Alfred Hulse Brooks, B. S., Washington, D. C. ; Assistant Geologist, U. S. Geological Survey. August, 1899.

Ernest Robertson Buckley, Ph. D., Rolla, Mo. State Geologist and Director of Bureau of Geology and Mines. June, 1902.

* Samuel Calvin, Iowa City, Iowa; Professor of Geology and Zoology in the State University of Iowa; State Geologist.

Henry Donald Campbell, Ph. D., Lexington, Va.; Professor of Geology and Biology in Washington and Lee University. May, 1889.

Marius R. Campbell, U. S. Geological Survey, Washington, D. C. August, 1892.

Franklin R. Carpenter, Ph. D., 1420 Josephine St., Denver, Colo.; Mining Engineer. May, 1889.

Ermine C. Case, Ph. D., Milwaukee, Wis.; Instructor in State Normal School. December, 1901.

*T. C. Chamberlin, LL. D., Chicago, Ill.; Head Professor of Geology, University of Chicago.

Clarence Raymond Claghorn, B. S., M. E., Wehrum, Indiana county, Pennsylvania. August, 1891.

*William Bullock Clark, Ph. D., Baltimore, Md.; Professor of Geology in Johns Hopkins University; State Geologist.

John Mason Clarke, A. M., Albany, N.Y.; State Paleontologist. December, 1897.

J. Morgan Clements, Ph. D., Madison, Wis.; Assistant Professor of Geology in University of Wisconsin. December, 1894.

Collier Cobb, A. B., A. M., Chapel Hill, N. C.; Professor of Geology in University of North Carolina. December, 1894.

Arthur P. Coleman, Ph. D., Toronto, Canada; Professor of Geology, Toronto University, and Geologist of Bureau of Mines of Ontario. December, 1896.

George L. Collie, Ph. D., Beloit, Wis.; Professor of Geology in Beloit College. December, 1897.

Arthur J. Collier, A. M., S. B., Washington, D. C.; Assistant Geologist, U. S. Geological Survey. June, 1902.

*Theodore B. Comstock, Los Angeles, Cal.; Mining Engineer.

*Francis W. Cragin, Ph. D., Colorado Springs, Colo.; Professor of Geology in Colorado College.

Alja Robinson Crook, Ph. D., Evanston, Ill.; Professor of Mineralogy and Petrography in Northwestern University. December, 1898.

*William O. Crosby, B. S., Boston Society of Natural History, Boston, Mass.; Asst. Prof. of Mineralogy and Lithology in Massachusests Inst. of Technology.

Whitman Cross, Ph. D., U. S. Geological Survey, Washington, D. C. May, 1889.

Garry E. Culver, A. M., 1104 Wisconsin St., Stevens Point, Wis. December, 1891.

Edgar R. Cumings, A. B., Bloomington, Ind.; Instructor in Geology, Indiana University. August, 1901.

*Henry P. Cushing, M. S., Adelbert College, Cleveland, Ohio; Professor of Geology, Western Reserve University.

*Nelson H. Darton, United States Geological Survey, Washington, D. C.

*William M. Davis, Cambridge, Mass.; Sturgis-Hooper Professor of Geology in Harvard University.

David T. Day, Ph. D., U. S. Geol. Survey, Washington, D. C. August, 1891.

Orville A. Derby, M. S., Sao Paulo, Brazil; Director of the Geographical and Geological Survey of the Province of Sao Paulo, Brazil. December, 1890.

*Joseph S. Diller, B. S., United States Geological Survey, Washington, D. C.

Edward V. d'Invilliers, E. M., 506 Walnut St., Philadelphia, Pa. Dec., 1888.

Richard E. Dodge, A. M., Teachers' College, West 120th St., New York city; Professor of Geography in the Teachers' College. August, 1897.

Noah Fields Drake, Ph. D., Tientsin, China; Professor of Geology in Imperial Tientsin University. December, 1898.

Charles R. Dryer, M. A., M. D., Terre Haute, Ind.; Professor of Geography, Indiana State Normal School. August, 1897.

*Edwin T. Dumble, Austin, Texas; State Geologist.

*William B. Dwight, Ph. B., Poughkeepsie, N. Y.; Professor of Natural History in Vassar College.

Arthur S. Eakle, Ph. D., Berkeley, Cal.; Instructor in Mineralogy, University of California. December, 1899.

Charles R. Eastman, A. M., Ph. D., Cambridge, Mass.; In charge of Vertebrate Paleontology, Museum of Comparative Zoology, Harvard University. December, 1895.

*George H. Eldridge, A. B., United States Geological Survey, Washington, D. C.

Arthur H. Elftman, Ph. D., 706 Globe Building, Minneapolis, Minn. Dec., 1898.

*Benjamin K. Emerson, Ph. D., Amherst, Mass.; Professor in Amherst College.

*Samuel F. Emmons, A. M., E. M., U. S. Geological Survey, Washington, D. C.

John Eyerman, F. Z. S., Oakhurst, Easton, Pa. August, 1891.

Harold W. Fairbanks, B. S., Berkeley, Cal.; Geologist State Mining Bureau. August, 1892.

*Herman L. Fairchild, B. S., Rochester, N. Y.; Professor of Geology in University of Rochester.

J. C. Fales, Danville, Kentucky; Professor in Centre College. December, 1888.

Oliver C. Farrington, Ph. D., Chicago, Ill.; In charge of Department of Geology, Field Columbian Museum. December, 1895.

August F. Foerste, Ph. D., 417 Grand Ave., Dayton, Ohio; Teacher of Sciences. December, 1899.

William M. Fontaine, A. M., University of Virginia, Va.; Professor of Natural History and Geology in University of Virginia. December, 1888.

*Persifor Frazer, D. Sc., 1042 Drexel Building, Philadelphia, Pa.; Professor of Chemistry in Horticultural Society of Pennsylvania.

*Homer T. Fuller, Ph. D., Springfield, Mo.; President of Drury College.

Myron Leslie Fuller, S. B., U. S. Geological Survey, Washington, D. C. December, 1898.

Henry Stewart Gane, Ph. D., Santa Barbary, Cal.; December, 1896.

Henry Gannett, S. B., A. Met. B., U. S. Geological Survey, Washington, D. C. December, 1891.

*Grove K. Gilbert, A. M., LL. D., U. S. Geological Survey, Washington, D. C.

Adam Capen Gill, Ph. D., Ithaca, N. Y.; Assistant Professor of Mineralogy and Petrography in Cornell University. December, 1888.

L. C. Glenn, Ph. D., Nashville, Tenn.; Professor of Geology in Vanderbilt University. June, 1900.

Charles H. Gordon, Ph. D., Lincoln, Neb.; Superintendent of Schools. August, 1893.

Amadeus W. Grabau, S. B., Columbia University, New York city; Lecturer on Paleontology. December, 1898.

Ulysses Sherman Grant, Ph. D., Evanston, Ill.; Professor of Geology, Northwestern University. December, 1890.

Herbert E. Gregory, Ph. D., New Haven, Conn.; Assistant Professor of Physiography, Yale University. August, 1901.

William S. Gresley, 115 Radbourne St., Derby, England; Mining Engineer. December, 1893.

George P. Grimsley, Ph. D., Topeka, Kans.; Professor of Geology in Washburn College. August, 1895.

Leon S. Griswold, A. B., 238 Boston St., Dorchester, Mass. August, 1892.

Frederic P. Gulliver, Ph. D., St. Mark's School, Southboro, Mass. August, 1895.

Arnold Hague, Ph. B., U. S. Geological Survey, Washington, D. C. May, 1889.

*Christopher W. Hall, A. M., 803 University Ave., Minneapolis, Minn.; Professor of Geology and Mineralogy in University of Minnesota.

John Burchmore Harrison, M. A., F. I. C., F. G. S., Georgetown, British Guiana; Government Geologist. June, 1902.

John B. Hastings, M. E., 20 Broad St., New York city. May, 1889.

John B. Hatcher, Ph. B., Carnegie Museum, Pittsburg, Pa. August, 1895.

*Erasmus Haworth, Ph. D., Lawrence, Kans.; Professor of Geology, University of Kansas.

C. Willard Hayes, Ph. D., U. S. Geological Survey, Washington, D. C. May, 1889.

*Angelo Heilprin, Academy of Natural Sciences, Philadelphia, Pa.; Professor of Paleontology in the Academy of Natural Sciences.

*Eugene W. Hilgard, Ph. D., LL. D., Berkeley, Cal.; Professor of Agriculture in University of California.

Frank A. Hill, Roanoke, Va. May, 1889.

*Robert T. Hill, B. S., U. S. Geological Survey, Washington, D. C.

Richard C. Hills, Mining Engineer, Denver, Colo. August, 1894.

*Charles H. Hitchcock, Ph. D., LL. D., Hanover, N. H.; Professor of Geology in Dartmouth College.

William Herbert Hobbs, Ph. D., Madison, Wis.; Professor of Mineralogy and Petrology, University of Wisconsin; Assistant Geologist, U. S. Geological Survey. August, 1891.

*Levi Holbrook, A M., P. O. Box 536, New York city.

Arthur Hollick, Ph. B., N. Y. Botanical Garden, Bronx Park, New York; Instructor in Geology, Columbia University. August, 1893.

*Joseph A. Holmes, Chapel Hill, N. C.; State Geologist and Professor of Geology, University of North Carolina.

Thomas C. Hopkins, Ph. D., Syracuse, N. Y.; Professor of Geology, Syracuse University. December, 1894.

*Edmund Otis Hovey, Ph. D., American Museum of Natural History, New York city; Assistant Curator of Geology.

*Horace C. Hovey, D. D., Newburyport, Mass.

*Edwin E. Howell, A. M., 612 Seventeenth St. N. W., Washington, D. C.

Lucius L. Hubbard, Ph. D., LL. D., Houghton, Mich. December, 1894.

Joseph P. Iddings, Ph. B., Professor of Petrographic Geology, University of Chicago, Chicago, Ill. May, 1889.

A. Wendell Jackson, Ph. B., 432 St. Nicholas Ave., New York city. Dec., 1888.

Robert T. Jackson, S. D., 9 Fayerweather St., Cambridge, Mass.; Instructor in Paleontology in Harvard University. August, 1894.

Thomas M. Jackson, C. E., S. D., Clarksburg, W. Va. May, 1889.

Alexis A. Julien, Ph., D., Columbia College, New York city; Instructor in Columbia College. May, 1889.

Arthur Keith, A. M., U. S. Geological Survey, Washington, D. C. May, 1889.

*James F. Kemp, A. B., E. M., Columbia University, New York city; Professor of Geology.

Charles Rollin Keyes, Ph. D., 944 Fifth St., Des Moines, Iowa. August, 1890.

Wilbur C. Knight, B. S., A. M., Laramie, Wyo.; Professor of Mining and Geology in the University of Wyoming. August, 1897.

Frank H. Knowlton, M. S., Washington, D. C.; Assistant Paleontologist, U. S. Geological Survey. May, 1889.

Edward Henry Kraus, Ph. D., Syracuse, N. Y.; Associate Professor of Mineralogy, Syracuse University, June, 1902.

Henry B. Kümmel, Ph. D., Trenton, N. J.; Assistant State Geologist. Dec., 1895.

*George F. Kunz, care Tiffany & Co., 15 Union Square, New York city.

George Edgar Ladd, Ph. D., Rolla, Mo.; Director School of Mines. August, 1891.

J. C. K. Laflamme, M. A., D. D., Quebec, Canada; Professor of Mineralogy and Geology in University Laval, Quebec. August, 1890.

Alfred C. Lane, Ph. D., Lansing, Mich.; State Geologist of Michigan. Dec., 1889.

Daniel W. Langton, Ph. D., 39 East Tenth St., New York city; Mining Engineer. December, 1889.

Andrew C. Lawson, Ph. D., Berkeley, Cal.; Professor of Geology and Mineralogy in the University of California. May, 1889.

Charles K. Leith, Ph. D., Madison, Wis; Assistant Professor of Geology, University of Wisconsin. December 1902.

Arthur G. Leonard, Ph. D., Des Moines, Iowa; Assistant State Geologist, Iowa Geological Survey. December, 1901.

*J. Peter Lesley, LL. D., Milton, Mass.

Frank Leverett, B. S., Ann Arbor, Mich.; Geologist, U. S. Geological Survey. August, 1890.

William Libbey, Sc. D., Princeton, N. J.; Professor of Physical Geography in Princeton University. August, 1899.

Waldemar Lindgren, U. S. Geological Survey, Washington, D. C. August, 1890.

George Davis Louderback, Ph. D., Reno, Nev.; Professor of Geology, University of Nevada. June, 1902.

Robebt H. Loughridge, Ph. D., Berkeley, Cal.; Assistant Professor of Agricultural Chemistry in University of California. May, 1889.

Thomas H. Macbride, Iowa City, Iowa; Professor of Botany in the State University of Iowa. May, 1889.

Henry McCalley, A. M., C. E., University, Tuscaloosa county, Ala.; Assistant on Geological Survey of Alabama. May, 1889.

Richard G. McConnell, A B., Geological Survey Office, Ottawa, Canada; Geologist on Geological and Natural History Survey of Canada. May, 1889.

James Rieman Macfarlane, A. B., 100 Diamond St., Pittsburg, Pa. August, 1891.

*W J McGee, Washington, D. C.; Bureau of North American Ethnology.

William McInnes, A. B., Geological Survey Office, Ottawa, Canada; Geologist, Geological and Natural History Survey of Canada. May, 1889.

Peter McKellar, Fort William, Ontario, Canada. August, 1890.

Curtis F. Marbut, A. M., State University, Columbia, Mo.; Instructor in Geology and Assistant on Missouri Geological Survey. August, 1897.

Vernon F. Marsters, A. M., Bloomington, Ind.; Professor of Geology in Indiana State University. August, 1892.

George Curtis Martin, Ph. D., Baltimore, Md.; Assistant in Paleontology, Johns Hopkins University. June, 1902.

Edward B. Mathews, Ph. D., Baltimore, Md.; Instructor in Petrography in Johns Hopkins University. August, 1895.

P. H. Mell, M. E., Ph. D., Clemson College, S. C.; President of Clemson College. December, 1888.

Warren C. Mendenhall, B. S., Washington, D. C.; Geologist, U. S. Geological Survey. June, 1902.

John C. Merriam, Ph. D., Berkeley, Cal.; Instructor in Paleontology in University of California. August, 1895.

*Frederick J. H. Merrill, Ph. D., State Museum, Albany, N. Y.; Director of State Museum and State Geologist.

George P. Merrill, M. S., U. S. National Museum, Washington, D. C.; Curator of Department of Lithology and Physical Geology. December, 1888.

Arthur M. Miller, A. M., Lexington, Ky.; Professor of Geology, State University of Kentucky. December, 1897.

Willet G. Miller, M. A., Toronto, Canada; Provincial Geologist of Ontario. December, 1902

Thomas F. Moses, M. D., Worcester Lane, Waltham, Mass. May, 1889.

*Frank L. Nason, A. B., West Haven, Conn.

*Peter Neff, A. M., 361 Russell Ave., Cleveland, Ohio.

Frederick H. Newell, B. S., U. S. Geol. Survey, Washington, D. C. May, 1889.

John F. Newsom, A. M., Stanford University, Cal.; Associate Professor of Metallurgy and Mining. December, 1899.

William H. Niles, Ph. B., M. A., Boston, Mass; Professor, Emeritus, of Geology, Mass. Inst. of Technology; Professor of Geology, Wellesley College. Aug., 1891.

William H. Norton, M. A., Mt Vernon, Iowa; Professor of Geology in Cornell College. December, 1895.

Charles J. Norwood, Lexington, Ky.; Professor of Mining, State College of Kentucky. August, 1894.

Ezequiel Ordonez, Esquela N. de Ingeneiros, City of Mexico, Mexico; Geologist del Instituto Geologico de Mexico. August, 1896.

*Amos O. Osborn, Waterville, Oneida County, N. Y.

Henry F. Osborn, Sc. D., Columbia University, New York city; Professor of Zoology, Columbia University. August, 1894.

Charles Palache, B. S., University Museum, Cambridge, Mass.; Instructor in Mineralogy, Harvard University. August, 1897.

*Horace B. Patton, Ph. D., Golden, Colo.; Professor of Geology and Mineralogy in Colorado School of Mines.

Frederick B. Peck, Ph. D., Easton, Pa.; Professor of Geology and Mineralogy, Lafayette College. August, 1901.

Samuel L. Penfield, Ph. B., M. A., New Haven, Conn.; Professor of Mineralogy, Sheffield Scientific School of Yale University. December, 1899.

Richard A. F. Penrose, Jr., Ph. D., 1331 Spruce St., Philadelphia, Pa. May, 1889.

George H. Perkins, Ph. D., Burlington, Vt.; State Geologist. Professor of Geology, University of Vermont. June, 1902.

Joseph H. Perry, 276 Highland St., Worcester, Mass. December, 1888.

*William H. Pettee, A. M., Ann Arbor, Mich.; Professor of Mineralogy, Economical Geology, and Mining Engineering in Michigan University.

Louis V. Pirsson, Ph. D., New Haven, Conn.; Professor of Physical Geology, Sheffield Scientific School of Yale University. August, 1894.

*Julius Pohlman, M. D., University of Buffalo, Buffalo, N. Y.

John Bonsall Porter, E. M., Ph. D., Montreal, Canada; Professor of Mining, McGill University. December, 1896.

Joseph Hyde Pratt, Ph. D., 74 Broadway, New York city. December, 1898.

*Charles S. Prosser, M. S., Columbus, Ohio; Professor of Geology in Ohio State University.

*Raphael Pumpelly, U. S. Geological Survey, Dublin, N. H.

Edmund C. Quereau, Ph. D., Aurora, Ill. August, 1897.

Frederick Leslie Ransome, Ph. D., Washington, D. C.; Assistant Geologist, U. S. Geological Survey. August, 1895.

Harry Fielding Reid, Ph. D., Johns Hopkins Univ., Baltimore, Md. Dec., 1892.

William North Rice, Ph. D., LL. D., Middletown, Conn.; Professor of Geology in Wesleyan University. August, 1890.

Charles H. Richardson, Ph. D., Hanover, N. H.; Instructor in Chemistry and Mineralogy, Dartmouth College. December, 1899.

Heinrich Ries, Ph. D., Cornell University, Ithaca, N. Y.; Assistant Professor in Economic Geology. December, 1893.

*Israel C. Russell, LL. D., Ann Arbor, Mich.; Professor of Geology in University of Michigan.

*James M. Safford, M. D., LL. D., Dallas, Texas.

Orestes H. St. John, Raton, N. Mex. May, 1889.

*Rollin D. Salisbury, A. M., Chicago, Ill.; Professor of General and Geographic Geology in University of Chicago.

Frederick W. Sardeson, Ph. D., Instructor in Paleontology, University of Minnesota, Minneapolis, Minn. December, 1892.

* Charles Schaeffer, M. D., 1309 Arch St., Philadelphia, Pa.

Frank C. Schrader, M. S., A. M., U. S. Geological Survey, Washington, D. C. August, 1901.

Charles Schuchert, Washington, D. C. ; Assistant Curator in Paleontology, U. S. National Museum. August, 1895.

William B. Scott, Ph. D., 56 Bayard Ave., Princeton, N. J. ; Blair Professor of Geology in College of New Jersey. August, 1892.

Henry M. Seely, M. D., Middlebury, Vt. ; Professor of Geology in Middlebury College. May, 1899.

* Nathaniel S. Shaler, LL. D., Cambridge, Mass. ; Professor of Geology in Harvard University.

George Burbank Shattuck, Ph. D., Baltimore, Md. ; Associate Professor in Physiographic Geology, Johns Hopkins University. August, 1899.

Edward M. Shepard, A. M., Springfield, Mo. ; Professor of Geology, Drury College. August, 1901.

Will H. Sherzer, M. S., Ypsilanti, Mich.; Professor in State Normal Sch. Dec., 1890.

* Frederick W. Simonds, Ph. D., Austin, Texas; Professor of Geology in University of Texas.

* Eugene A. Smith, Ph. D., University, Tuscaloosa County, Ala. ; State Geologist and Professor of Chemistry and Geology in University of Alabama.

Frank Clemes Smith, B. S., 159 La Salle St , Chicago, Ill.; Mining Engineer. December, 1898.

George Otis Smith, Ph. D., Washington, D. C. ; Assistant Geologist, U. S. Geological Survey. August, 1897.

William S. T. Smith, Ph. D., Washington, D. C. ; Assistant Geologist, U. S. Geological Survey. June, 1902.

* John C. Smock, Ph. D., Trenton, N. J. ; State Geologist.

Charles H. Smyth, Jr., Ph. D., Clinton, N. Y. ; Professor of Geology in Hamilton College. August, 1892.

Henry L. Smyth, A. B., Cambridge, Mass. ; Professor of Mining and Metallurgy in Harvard University. August, 1894.

Arthur Coe Spencer, B. S., Ph. D., Washington, D. C. ; Assistant Geologist, U. S. Geological Survey. December, 1896.

* J. W. Spencer, Ph. D., 1733 Q St. N. W., Washington, D. C.

Josiah E. Spurr, A. B., A. M., U. S. Geological Survey, Washington, D. C. December, 1894.

Joseph Stanley-Brown, 128 Broadway, New York. August, 1892.

Timothy William Stanton, B. S., U. S. National Museum, Washington, D. C. ; Assistant Paleontologist, U. S. Geological Survey. August, 1891.

* John J. Stevenson, Ph. D., LL. D., New York University ; Professor of Geology in the New York University.

William J. Sutton, B. S., E. M., Victoria, B. C. ; Geologist to E. and N. Railway Co. August, 1901.

Joseph A. Taff, B. S., Washington, D. C. ; Assistant Geologist, U. S. Geological Survey. August, 1895.

James E. Talmage, Ph. D., Salt Lake City, Utah. Professor of Geology in University of Utah. December, 1897.

Ralph S. Tarr, Cornell University, Ithaca, N. Y. ; Professor of Dynamic Geology and Physical Geography. August, 1890.

Frank B. Taylor, Fort Wayne, Ind. December, 1895.

William G. Tight, M. S., Albuquerque, N. Mex. ; President and Professor of Geology, University of New Mexico. August, 1897.

* James E. Todd, A. M., Vermilion, S. Dak. ; Professor of Geology and Mineralogy in University of South Dakota.

* Henry W. Turner, B. S., U. S. Geological Survey, San Francisco, Cal.

JOSEPH B. TYRRELL, M. A., B. Sc., Dawson, Y. T., Canada. May, 1889.

JOHAN A. UDDEN, A. M., Rock Island, Ill. ; Professor of Geology and Natural History in Augustana College. August, 1897.

* WARREN UPHAM, A. M., Librarian Minnesota Historical Society, St. Paul, Minn.

* CHARLES R. VAN HISE, M. S., Madison, Wis. ; Professor of Geology, University of Wisconsin ; Geologist, U. S. Geological Survey.

FRANK ROBERTSON VAN HORN, Ph. D., Cleveland, Ohio ; Professor of Geology and Mineralogy, Case School of Applied Science. December, 1898.

THOMAS WAYLAND VAUGHAN, B. S., A. M., Washington, D. C. ; Assistant Geologist, U. S. Geological Survey. August, 1896

*ANTHONY W. VOGDES, San Diego, Cal. ; Captain Fifth Artillery, U. S. Army.

* MARSHMAN E. WADSWORTH, Ph. D., State College, Pa. ; Professor of Mining and Geology, Pennsylvania State College.

* CHARLES D. WALCOTT, Washington, D. C. ; Director U. S. Geological Survey.

CHARLES H. WARREN, Ph D., Boston, Mass. ; Instructor in Geology, Massachusetts Institute of Technology. December, 1901.

HENRY STEPHENS WASHINGTON, Ph. D., Locust, Monmouth Co., N. J. ; Aug., 1896.

THOMAS L. WATSON, Ph. D., Granville, Ohio ; Professor of Geology, Denison University. June, 1900.

WALTER H. WEED, M. E , U. S. Geological Survey, Washington, D. C. May, 1889.

STUART WELLER, B. S., Chicago, Ill. Instructor in University of Chicago. June, 1900.

LEWIS G. WESTGATE, Ph. D., Delaware, Ohio ; Professor of Geology, Ohio Wesleyan University.

THOMAS C. WESTON, 76 St. Joachim St., Quebec, Canada. August, 1893.

DAVID WHITE, U. S. National Museum, Washington, D. C. ; Assistant Paleontologist, U. S. Geological Survey, Washington, D. C. May, 1889.

* ISRAEL C. WHITE, Ph. D., Morgantown, W. Va.

* ROBERT P. WHITFIELD, Ph. D., American Museum of Natural History, 78th St. and Eighth Ave., New York city ; Curator of Geology and Paleontology.

* EDWARD H. WILLIAMS, JR., A. C., E. M., 117 Church St., Bethlehem, Pa. ; Professor of Mining Engineering and Geology in Lehigh University.

* HENRY S. WILLIAMS, Ph. D., New Haven, Conn. ; Professor of Geology and Paleontology in Yale University.

BAILEY WILLIS, U. S. Geological Survey, Washington, D. C. December, 1889.

SAMUEL W. WILLISTON, Ph. D., M. D., Chicago, Ill. ; Professor of Paleontology, University of Chicago. December, 1898.

ARTHUR B WILLMOTT, M. A., Sault Ste. Marie, Ontario, Canada. December, 1899.

ALFRED W, G. WILSON, Ph. D., Montreal, Ont., Canada ; Demonstrator in Geology, McGill University. June, 1902.

ALEXANDER N. WINCHELL, Doct. U. Paris, Butte, Mont. ; Professor of Geology and Mineralogy, Montana State School of Mines. August, 1901.

* HORACE VAUGHN WINCHELL, Butte, Montana ; Geologist of the Anaconda Copper Mining Company.

* NEWTON H. WINCHELL, A. M., Minneapolis, Minn. ; State Geologist ; Professor in University of Minnesota.

*ARTHUR WINSLOW, B. S., care of United States and British Columbia Mining Company, 104 W. 9th St., Kansas City, Mo.

JOHN E. WOLFF, Ph. D., Harvard University, Cambridge, Mass. ; Professor of Petrography and Mineralogy in Harvard University and Curator of the Mineralogical Museum. December, 1889.

ROBERT S. WOODWARD, C. E., Columbia College, New York city ; Professor of Mechanics in Columbia College. May, 1889.

JAY B. WOODWORTH, B. S., 24 Langdon St., Cambridge, Mass. ; Instructor in Harvard University. December, 1895.

ALBERT A. WRIGHT, Ph. D., Oberlin, Ohio; Professor of Geology in Oberlin College. August, 1893.

*G. FREDERICK WRIGHT, D. D., Oberlin, Ohio; Professor in Oberlin Theological Seminary.

WILLIAM S. YEATES, A. B., A. M., Atlanta, Ga.; State Geologist of Ga. Aug., 1894.

FELLOWS DECEASED

*Indicates Original Fellow (see article III of Constitution)

*CHARLES A. ASHBURNER, M. S., C. E. Died December 24, 1889.
AMOS BOWMAN. Died June 18, 1894.
*J. H. CHAPIN, Ph. D. Died March 14, 1892.
GEORGE H. COOK, Ph. D., LL. D. Died September 22, 1889.
*EDWARD D. COPE, Ph. D. Died April 12, 1897.
ANTONIO DEL CASTILLO. Died October 28, 1895.
*EDWARD W. CLAYPOLE, D. Sc. Died August 17, 1901.
*JAMES D. DANA, LL. D. Died April 14, 1895.
GEORGE M. DAWSON, D. Sc. Died March 2, 1901.
Sir J. WILLIAM DAWSON, LL. D. Died November 19, 1899.
*ALBERT E. FOOTE. Died October 10, 1895.
N. J. GIROUX, C. E. Died November 30, 1890.
*JAMES HALL, LL. D. Died August 7, 1898.
*ROBERT HAY. Died December 14, 1895.
DAVID HONEYMAN, D. C. L. Died October 17, 1889.
THOMAS STERRY HUNT, D. Sc., LL. D. Died February 12, 1892.
*ALPHEUS HYATT, B. S. Died January 15, 1902.
*JOSEPH F. JAMES, M. S. Died March 29, 1897.
RALPH D. LACOE. Died February 5, 1901.
*JOSEPH LE CONTE, M. D., LL. D. Died July 6, 1901.
OLIVER MARCY, LL. D. Died March 19, 1899.
OTHNIEL C. MARSH, Ph. D., LL. D. Died March 18, 1899.
JAMES E. MILLS, B. S. Died July 25, 1901.
*HENRY B. NASON, M. D., Ph. D., LL. D. Died January 17, 1895.
*JOHN S. NEWBERRY, M. D., LL. D. Died December 7, 1892.
*EDWARD ORTON, Ph. D., LL. D. Died October 16, 1899.
*RICHARD OWEN, LL. D. Died March 24, 1890.
*FRANKLIN PLATT. Died July 24, 1900.
*JOHN WESLEY POWELL, LL. D. Died September 23, 1902.
CHARLES WACHSMUTH. Died February 7, 1896.
THEODORE G. WHITE, Ph. B., A. M. Died July 7, 1901.
*GEORGE H. WILLIAMS, Ph. D. Died July 12, 1894.
*J. FRANCIS WILLIAMS, Ph. D. Died November 9, 1891.
*ALEXANDER WINCHELL, LL. D. Died February 19, 1891.

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